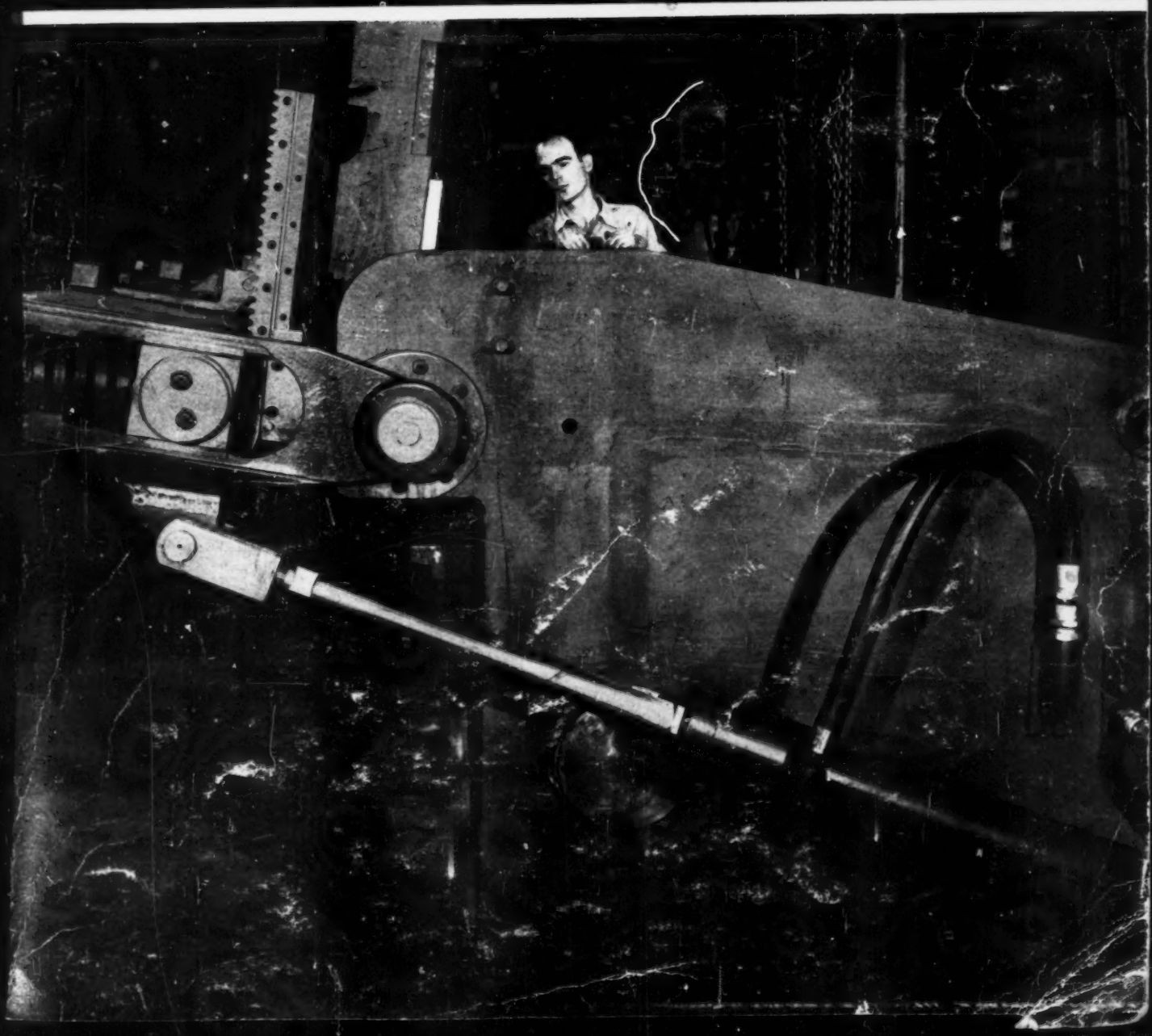
Applied HYDRAULICS



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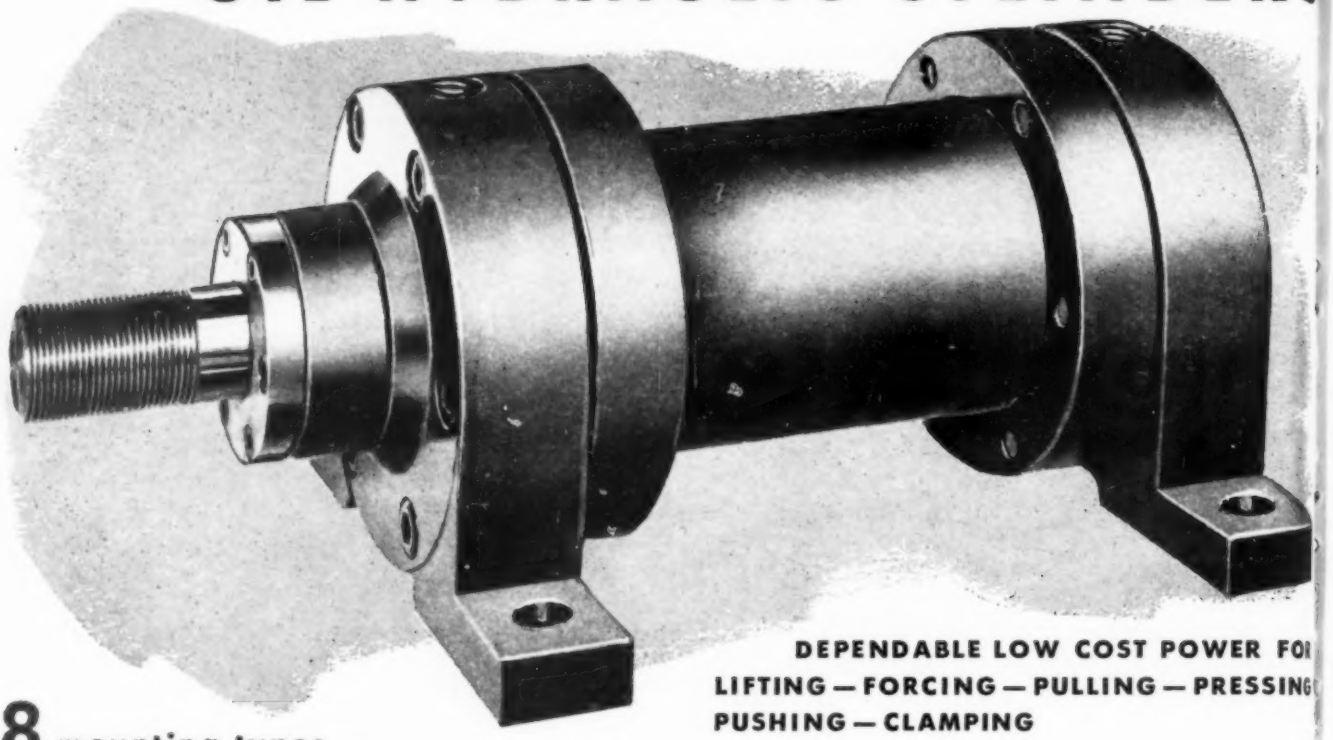

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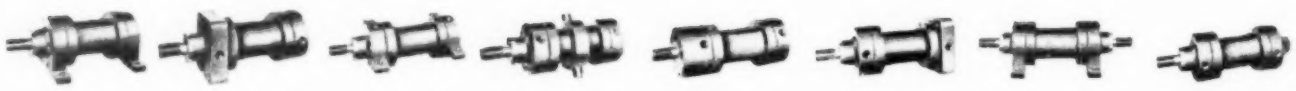

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LINDBERG OIL HYDRAULIC CYLINDERS

Vol. 1 No. 1

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FRONT COVER: The hydraulically actuated machine is shown performing a bending operation. The power cylinder piston is fully extended and the fixture holding the work is vertical. Story on page 28.

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Photo courtesy of
Kane & Roach, Inc.
Syracuse, N. Y.

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The "Flying Cut-Off" pictured here is used for forming, from strip coiled stock, two channels rolled simultaneously. The material is drawn from two separate coils, passes through a leveller and flying cut-off and goes into the forming machine. When a predetermined length of stock has been drawn through, the accumulators instantly release a supply of fluid pressure which is used for the actual cutting operation.

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WE MAKE OUR BOW

WE ARE pleased to bring you, with this issue, the first magazine in the history of industrial America devoted exclusively to the science of applied hydraulics.

The hydraulic field is huge. This magazine will interest itself only with those phases which involve the transmission of power through the use of pressure on hydraulic fluids.

Over twenty-five industries make important use of hydraulic mechanisms for actuation and control. The use of this method of applying power in industry has grown tremendously over the past few years and gives every promise of a much greater growth in the foreseeable future.

We learned much through our wartime aviation program because numerous hydraulic applications were designed into every plane we built. We are now busily engaged in applying that knowledge to the peaceful pursuits of industry.

Applied Hydraulics will have a single goal. It will "sell" hydraulics. Nothing more and nothing less. This will be a threefold program. It will "sell" at the management level by demonstrating to production executives the efficiencies and advantages gained from the use of hydraulic power and mechanisms. It will "sell" at the engineering level by showing engineers how hydraulic mechanisms can be used most advantageously. Lastly, it will "sell" at the maintenance level by showing maintenance men how to keep their present hydraulically equipped machinery operating at peak efficiency.

We approach our job with all humility because we know it is a big job and one that carries with it a real responsibility. We hope we'll make no mistakes as we tackle this pioneering job. If and when we do, we hope our readers will bear with us, and will help us.

We'll visit you each month; we pledge our very best efforts to bring you the business and technical information that will be helpful.

Irving B. Dexter

DEVELOPMENTS IN HYDRAULIC TRANSMISSIONS

Paper delivered at the Third Annual Meeting, National Conference on Industrial Hydraulics, Chicago, October 17, 1947.

R. H. HENSLEIGH
Consulting Engineer
Detroit, Michigan

AT THE PRESENT TIME, almost every automobile manufacturer is working on some kind of hydraulic transmission. The advantages of transmitting power hydraulically are being recognized by engineers and laymen alike. In the past few years, the successful record of hydraulics, in performing jobs that would have been considered impossible by other methods, has stimulated a great deal of interest.

Two Types of Transmissions

Perhaps, in starting, it would be best to briefly describe the two basic types of hydraulic transmissions—the hydrostatic transmission employs positive displacement pumps and motors of either the gear, piston, or vane types to circulate the oil in the system. The power is transmitted by causing a pressure rise in the pump and a pressure drop in the hydraulic motor. Since the oil returns to the pump with the same velocity with which it left, there is no kinetic enegery transfer, so the system is called "hydrostatic".

However, in the hydrokinetic transmission, the energy transfer is accomplished through changes in the velocity of the oil as it passes through the pump and turbine, pressure changes being avoided as far as possible. The hydrokinetic transmission is usually composed of a centrifugal pump and a hydraulic reaction turbine mounted co-axially in the same case, which is filled with oil. Without a reaction stage, the transmission becomes a fluid clutch, such as used in the Chrysler Fluid Drive, or in General Motors' Hydramatic.

Many applications for hydraulic transmissions have been found in recent years—machine tools, automobiles and trucks, tractors, power shovels, rail cars, switch locomotives, gun tractors and tanks, oil well rigs and other heavy equipment, aircraft and so, on and on.

In many of these installations, hydraulic transmissions satisfactorily solved problems which were seemingly impossible by other means, and have completely superseded more conventional transmissions in many cases. Quite frequently, hydraulic transmissions have replaced standard transmissions just on size, cost, or weight considerations. But, more often, they are used because of one or more of their peculiar functional advantages—that is, the engineer may require a transmission which will quickly accelerate a heavy load without jerks or interruptions, as in winches and cranes, buses and rail cars. Or, perhaps, precise control of speed or torque must be maintained through wide ranges, as in machine tools, roll drives for steel and paper mills, or in automatic computing gun turrets. Sometimes, power must be delivered to a place too small for an electric motor, and impossible to get at with shafts, gears and belts. In automobiles and buses, better performance on less gasoline, with more comfort for the passengers and less fatigue for the driver are the advantages being considered by chief engineers and sales personnel throughout the country.

Advantages and Disadvantages

Hydrostatic and hydrodynamic transmissions each have their own peculiar characteristics: advantages and disadvantages. The hydrostatic transmission possesses extreme flexibility in installation—the power may be transferred to some inaccessible place through tubes or flexible hoses, while hydrodynamic transmissions are compact, self-contained units with concentric shafts. The hydrostatic transmission may be pre-set

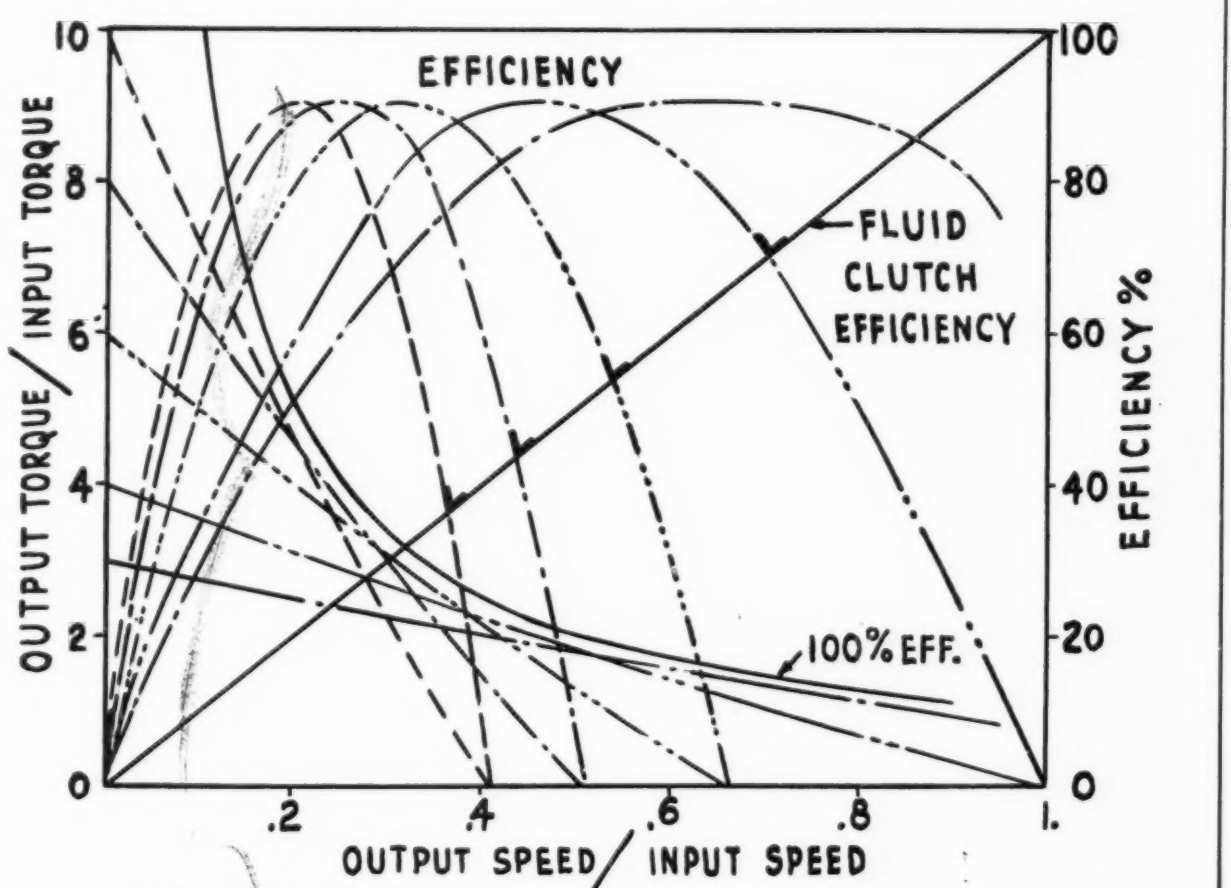
to maintain practically any speed ratio through wide variations in torque, while the hydrokinetic transmission, being essentially a self-regulating device, needs no external controls, but must be carefully tailored to match the engine and its load during the initial design stages. The hydrostatic transmission may be reversed or idled by means of a simple four-way valve, while the hydrodynamic transmission generally requires a more complicated gear and clutch arrangement for neutral and reverse. Hydrostatic transmissions have been found suitable for small, low power applications requiring precise control, while hydrodynamic transmissions are better adapted for transmitting large amounts of power, because of their small size, low cost and weight. Both types offer smooth, uninterrupted variations in speed and torque ratios, overload and shock protection for both the driving motor and the driven load.

Either type of hydraulic transmission may be used to make substantial gains in fuel economy by holding an engine to its most efficient speed. The 10 or 15 percent loss in the transmission is negligible compared with part-throttle pumping and friction losses in an internal combustion engine, when run with a stepped-ratio transmission.

The Hydrostatic Transmission

Unfortunately, neither type of hydraulic transmission is easy to develop into a finished product. The hydrostatic transmission, while it is easy to calculate its performance characteristics, presents mechanical difficulties—high thrust and radial loads on its bearings, high stresses in some of its other parts, the necessity for extreme accuracy in machining, and sometimes, difficult sealing problems, but the hydrodynamic transmission, while it has practically no bearing loads or high stresses to contend with, essentially nothing to wear out and very little machining in it, its performance is quite difficult to calculate, and the number of compromises that must be made in order to achieve the optimum performance in each installation is staggering. Actually, the hydrostatic transmissions are developed in the experimental laboratory after they are designed and built, but the most difficult part of the development of a hydrodynamic transmission comes before it ever gets to a drawing board for the design of the actual parts. After the transmission is built, a test stand will just tell you that something is wrong, not what is wrong. With the hydrostatic transmission, a part will at least wear out or break, and you can go to work on that, but a torque converter will just sit there and keep on running. Its efficiency may be poor, but it won't tell you why. The engineer must take his choice of wading through weeks of tedious calculations, or subjecting his company to months of expensive cut-and-try procedure.

One of the best examples of satisfactory performance under exacting requirements for the hydrostatic transmission was the unit built for



Graph showing torque multiplication and efficiency curves vs speed ratio for a family of similar hydrodynamic transmissions, each designed for a different application, compared with hyperbola of 100 percent efficiency.

our power-operated gun turrets during the war. Thousands of these little transmissions were used to give infinitely variable rates of change of azimuth and elevation for these guns. The deadly accuracy of our anti-aircraft guns on the ground, and the machine guns in our bombers was due to a great extent to the precision with which these transmissions positioned the guns in response to automatic computing sights, directors and radar tracking equipment. One model of this transmission, as used in the upper turret and ball turret of the B-17, was about the size of a 6-inch cube, weighed 20 pounds, and was good for about 2½ horsepower. Its infinitely variable speed ratios were produced by changing the displacement of the pump, which fed a fixed displacement hydraulic motor.

Transmissions of the hydrostatic type similar to the one just described have been successfully used in many other applications: machine tool spindle drives, drives for rolls in paper mills, and in many other applications requiring precise control over small amounts of power, and where the cost, size, and weight is negligible, compared to the operations and processes which they make possible. They have been made in sizes ranging up to several hundred horsepower, and for aircraft, with weight as low as 1.3 pounds per horsepower.

Several experimental automobiles have been built in recent years with infinitely variable hydrostatic transmissions, but so far, none of these transmissions have been used in production automobiles. The chief advantage of this transmission, as applied to an automobile, lies in its ability to maintain any speed ratio necessary to achieve the highest over-all power-plant efficiency. This type of transmission also makes possible the use of engines having little flexibility of their own, such as the diesel and the two-cycle, and further, it can be automatically controlled to take a great deal of work out of driving. The main reasons that these transmissions have not reached automotive production are their high weight and cost, but it is quite possible that a properly conducted development program will evolve a design which will meet the requirements of the automotive industry, possibly in the near future.

The Hydrokinetic Transmission

According to the history books, the first hydrokinetic transmissions or hydraulic torque converters were designed as reduction gears between steam turbines and propellers for ships before the development of herringbone gears for this purpose. Apparently, there was little intention of using the hydrokinetic transmission for an infinitely variable speed reducer, as it is used today. But, in the past fifty years, these transmissions have changed considerably. A great deal of progress has been made in understanding the internal functioning of the converter—that is, finding out what happens to streams of oil flowing through stages of blades at 60 or 70 miles an hour.

The hydraulic torque converter by itself, is usually insufficient to perform most transmission jobs, and must have additional equipment combined with it, such as provisions for neutral and reverse, lock-up drive, auxiliary gear changes, etc. Transmissions embodying torque converters differ as much in the auxiliary equipment as they do in the converter itself, and the selection of this

"Hydrostatic transmissions have been found suitable for small, low power applications requiring precise control; hydrodynamic transmissions are better adapted for transmitting large amounts of power, because of their small size, low cost and weight. Both types offer smooth, uninterrupted variations in speed and torque ratios, overload and shock protection for both the driving motor and the driven load."

equipment by various manufacturers shows several different philosophies concerning the use of the converter. For example: Spicer, Twin Disc and GM Coach in this country and Leyland in England, all using the Lysholm-Smith design, whose efficiency peak occurs at a relatively low speed ratio, have used the torque converter only for acceleration of the load, and a lock-up clutch mechanism for driving after sufficient speed had been attained. Schneider Brothers, Bendix, General Motors Experimental and Warner Gear, as well as several foreign manufacturers, all using converters whose peak efficiency occurred at a high speed ratio, have combined the functions of the hydrokinetic transmission with that of a fluid clutch, by allowing the reaction stage of blades to free-wheel once a 1 to 1 torque ratio had been reached. One recent experimental transmission carried this idea still further, using three reaction stages in series, each succeeding stage free-wheeling at a slightly higher speed ratio. By breaking up the stator in this manner, a quite broad, and almost flat, efficiency curve was obtained. Some other hydrodynamic transmissions have used pivoted blades so that the angle of attack of the fluid with respect to the blade might be changed, in order to attain a broad, flat efficiency curve.

Torque Converter Applications

One application of the Lysholm-Smith torque converter that differed considerably from previous installations, was in the General Motors transmission for tanks and gun tractors. Here, the torque converter remained in the power train continuously, a sufficient amount of ratio change being provided in the semi-automatic planetary gear-box between the converter and the final drive. This gear-box was interesting, in that all the gear ratios were overdrives, except low, which was 1 to 1. This was done to reduce the load handled by the steering brakes. The efficiency of the torque converter was maintained at a satisfactory level by simply changing gear ratios as the efficiency of the torque converter approached an unfavorable speed ratio. This combination gave very satisfactory performance in tanks and tank-destroyers, and is now being considered for a heavy track-type tractor.

There are several noteworthy features in the White Hydro Torque truck and bus transmission using the Schneider Brothers converter. One of these is the supercharge pressure of 40 psi maintained in the converter by a separate pump. This raises the stall torque by preventing cavitation when the velocities become excessive. Another pump is used to pick up oil that leaks past the piston ring shaft seals, obviating the necessity for bulky and complicated seals of other types. Automatic control of the gear shifts in this transmission is achieved through a governor which is sensitive to the difference between input and output speeds.

It seems that some advantage might be gained by using a control which is sensitive to the ratio of the input and output speeds, as the characteristics of a hydrokinetic transmission are definitely related to the ratio, rather than the differential. To accomplish this may at first appear complicated, but I know of a hydraulic control system developed during the war, which continuously solved a long equation, multiplying

and dividing, adding and substracting, and taking logarithms, and it wasn't very big or complicated either.

The most recent successful foreign hydrodynamic transmission that has come to my attention is the English Brockhouse, which is in production for one of the larger English passenger cars. This converter has two turbine stages and two reaction stages, one between the turbine sections, the other between the second turbine and the pump. Both stator stages free-wheel at high speed ratios. The stall ratio has been reported to be 4.2, and the peak efficiency 87 percent.

Converter for Speed Multiplication

While all of the well-known hydraulic torque converters have been built for torque multiplication, at least one, which is now in the development stage, was designed for a speed multiplication. This transmission, designed to drive a supercharger, while its first test runs have not been too successful due to its poor efficiency in the low speed ratios, and its inability to accelerate the load into the high efficiency range, may be interesting from the academic standpoint. It has been proven that good efficiencies can be achieved at step-up ratios as high as 5 or 6 to 1.

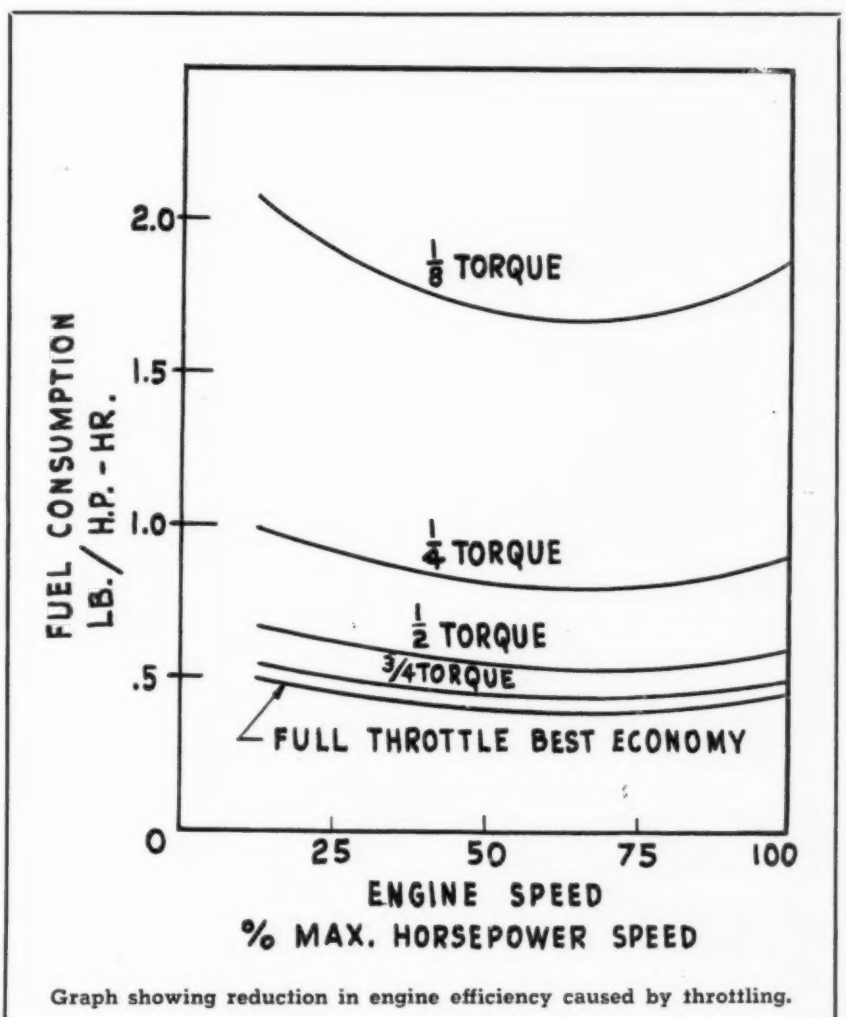
One of the widely publicized features of the new Tucker rear-engine car is its torque converter drive. The engine is mounted transversely, with the crankshaft where the rear axel would be, with a hydrodynamic transmission driving each rear wheel independently. To use two transmissions in one automobile might sound expensive. However, cost analyses have shown this to be cheaper than a semi-automatic gear-type transmission and differential. The added traction provided by the independent drive is an extra advantage. The requirements for this transmission were about as tough as any I've ever seen: for ground clearance, the diameter could be no greater than 15 inches, in spite of an input torque of 225 foot-pounds at 1000 rpm, torque multiplication of 4.7, and a universal joint just 5 inches from the end of the crankcase! But after trying for weeks to convince Mr. Tucker that it couldn't be done, we just went ahead and did it anyway.

There are no gears between the crankshaft and the wheels, not even for reverse. (We aren't the least bit allergic to gears—there just wasn't space for any.) The pump of the converter has constant torque characteristics, to hold the engine close to its full-throttle capacity at all speeds, and the turbine and stator sections have been designed in such a way as to give high efficiency over a broad enough range to allow the drive to be through the converter at all times.

For years, it has seemed to me that we have given far too much attention to high compression ratios and high octane gasoline, and far too little attention to the transmission. The transmission is highly efficient in itself with respect to the ratio of output power to input power, but it renders our engine efficiency achievements ineffective by letting the engine run away, as much as half its power going to pump air through a throttle valve, and drive all its parts at twice the necessary speed.

We could have our cake, and eat it too. The popular belief that a car with a powerful engine must make poor gas mileage is not necessarily so. Specific fuel consumption is generally just a little *BETTER* with large engines than it is with small ones. It's a miscarriage of justice to condemn the engine for crimes of a "make-shift" transmission. A Cadillac can be operated at 35 miles per gallon at 35 miles per hour, by slightly leaning-out the carburetor, and installing the right transmission. It *doesn't* have to be over 90 percent efficient, either.

It is to the successful record of hydraulics in meeting the challenge of some of the tough jobs just mentioned, that we owe our present opportunities in this field. Each tough new job, every fresh challenge, presents a new opportunity. And when it comes to opportunity, I can't seem to forget what my grandfather used to say—"When opportunity gets ready to let a few drops out of the faucet, you want to be standing right there with a wash tub!"



Graph showing reduction in engine efficiency caused by throttling.

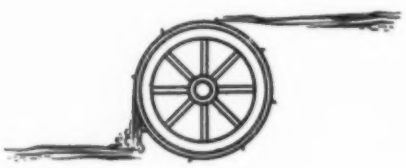
THE A B C's OF

A Hydraulic system using oil as a medium is basically a very simple means of utilizing power transmitted by fluid pressure to perform mechanical work.

A HYDRAULIC SYSTEM is definable as a group of elements which work as a unit to transmit power by means of fluid pressure to do useful mechanical work.

Let us go a step behind this definition so that we are sure we understand exactly what it means.

First, we must dismiss the idea that there is any mystery about hydraulics. The word itself means water and is a reminder that the earliest use of the power of fluid in motion was with water. Water hydraulics became early and remains



an important field with many applications.

Oil is the second fluid utilized for power transmission. Since modern industrial power requirements can nearly always be met by oil systems, we will concern ourselves exclusively with the use of oil as the fluid medium.

It is important that we have a clear idea how power can be transmitted by fluid pressure. A basic illustration is the turning of a water wheel. Fluid pressure—in this case rapidly flowing and falling water—is exerted against the paddles of a wheel, turning the wheel and its simple mechanism to perform grinding or other operations directly. The water turbine is a lineal descendent of the water wheel.

Oil can be used in much the same way to transmit power. Obviously, oil cannot be let run free as water is. A means must be employed to utilize the oil over and over. This is done by a transmission system which is simply a closed circuit of piping and tubing.

When oil is used as the fluid medium the same power transmission is created. In an oil hydraulic system a pump is used to build up the pressures required and various devices are placed in the oil circuit to utilize the power for useful work, to regulate the pressures, to transmit the power in the desired direction and as needed and to return the oil to the pump.

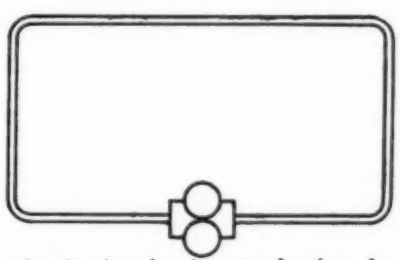
Let us check a moment to see if we are clear up to this point. Our hydraulic system uses oil as its power fluid, the force built up by a pump is transmitted through control devices to operate a mechanical power element and the oil, still under directional and pressure control, is returned to the starting point. The entire system is closed, so that theoretically, no oil is lost from cycle to cycle.

Individual Elements

We are now ready to examine the individual elements of our basic system.

On our diagram "A" represents a pump. A pump is a mechanical device for moving fluids under pressure. There are many types of pumps designed to move fluids under many pressure requirements but they all do the same basic job—they exert force on the fluid, causing it to move through the transmission lines—they create the force to transmit power.

Valves are very important elements of hydraulic systems. It is essential we understand just what a



valve is. A valve is a mechanism designed to control the direction of flow, the volume or the pressure of a fluid.

Valves function much like a traffic cop at a busy intersection. The work that is to be performed may require that the flow be in one direction for one part of the work cycle and reversed or in another direction for another part of the cycle.

HYDRAULIC SYSTEM

This is exactly analogous to a flow of street traffic. Under some conditions an excess of fluid pressure must be diverted or by-passed. This is like a diversion of excess traffic to side streets.

Valves are often given names from the type of job they do. We will see that this is true of the valves in our simple system.

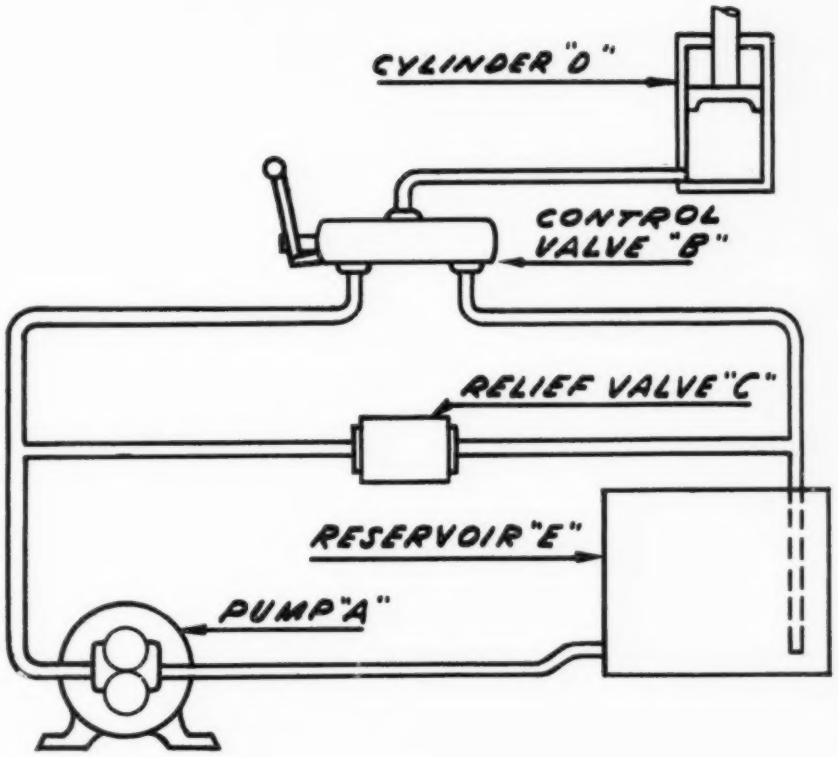
The next element "B" is the work controlling valve and for this reason is called the control valve. Our control valve is hand operated, which means the operator must move the control handle to actuate the working stroke. This handle movement "opens" the valve permitting the flow of fluid through it.

This brings us to our relief valve marked "C". A relief valve regulates the maximum pressure in a hydraulic system. It provides for excess fluid to return to the reservoir without pressure fluctuations disturbing the designed functions of the system. It acts as a protection against the development of dangerout pressures by the pump. The relief valve is frequently installed in the transmission piping as near the pump discharge outlet as practicable for this reason. In some instances, the relief valve is built into the pump itself or control valve.

The next element "D" is the work performing part of the system. A cylinder is represented with its piston in the forward part of its power stroke. The cylinder is single acting, that is, transmission lines enter or supply one end of the cylinder only.

The transmission of power up to this point is from the power source, the pump, through the transmission lines and control valve to the rear of the piston in the cylinder which performs the work.

One more element is essential if the system is to operate continuously. This is a means of removing the fluid from the work cylinder. This must be done positively and safely.



The operator at the end of the work stroke shifts the handle on the control valve. This cuts off the delivery flow and permits the oil to drain from the work cylinder through the control valve into the transmission line to the reservoir. In case the operator does not operate this handle, the excess pressure causes the relief valve to open and by-pass a part of the flow to the reservoir line.

Our last essential element is the reservoir, marked "E" on the diagram.

The reservoir is a storage tank for the fluid. It is often equipped with filters and cooling devices. It should be large enough to provide fluid for long periods of continuous operation, allowing for normal line losses and permit the agitated return oil to dissipate at least part of its elevated temperature and to regain its physical stability.

The outlet line from the reservoir is the inlet line to the pump.

We can now visualize the entire cycle of operation. The pump is started and builds pressure by forcing fluid into its discharge line. The relief valve, acting like a traffic cop, regulates the pressure supplied to the control valve. Opening of the control valve permits delivery of power to the work cylinder, the piston of which advances, performing its work stroke. At the end of this stroke, the operator reverses the control valve, allowing the fluid to drain from the rear of the work cylinder. If the control valve is not reversed, the flow is by-passed through the relief valve to the reservoir.

Hydraulic power using oil as a medium is basically a very simple means of utilizing power transmitted by fluid pressure to perform mechanical work.

With long-boomed cranes assisting and salvage pumps building buoyancy, the battleship "California" rises to the surface of Pearl Harbor.
Official U. S. Navy Photograph

THE DAMAGE at Pearl Harbor—eight battle ships and ten other warships sunk or disabled—called for one of the most urgent salvage jobs in history. The most critical part of the salvage was to clear the entrance channel of the harbor. The securing of cables, the enormous lifting power required and the delicacy of the actual lifting and righting of 30,000 ton hulks called for more large specially equipped cranes and hoists than the entire Navy possessed. Industry rose to the occasion.

Six of the cranes or hoists used for the job were Manitowac Model 3000 cranes with a 50 ton capacity at a 12 foot hoisting radius. All six cranes were hydraulic torque converter equipped. The Manitowoc Engineering Works, Manitowoc, Wisc., had three converters installed on completed cranes awaiting shipment. The converters were immediately stripped from the completed cranes and installed in the 50 ton cranes required by the Navy. The first crane was actually shipped within a week. One converter each was shipped on January 3, 6 and 9, which permitted Manitowoc to ship their last unit within six weeks after receipt of the order from the Navy Department.

The salvage job was complicated by the fact that several battleships lay in forty to sixty feet of soft mud. It was necessary to run cables around the hulls and hold the dead weight of the water-filled ships while the mud was sludged away, emergency repairs made, the holds pumped clear and the delicate raising and righting operations completed.

This operation involved torque converter equipped hoists produced by the Winch and Hoist Division of Six Wheels, Inc., Los Angeles. Six Wheels, Inc., placed an order on December 16, 1941, for twelve hydraulic torque converters supported by a AA priority rating. Seven of the converters were shipped before the end of the month and the balance of five units went forward the week of January 5th, making it possible for Six Wheels, Inc., to make delivery of their salvaging hoists in record time.

The splendid job that Six Wheels, Inc., did in delivering the twelve salvaging hoists to the Navy had one interesting background incident which is released now for the first time. One day in November, 1940, a naval salvage engineer walked into the Six Wheels, Inc., office. He laid down specifications for a hoist that was to be powered by an internal combustion engine but which had to exhibit the power ability and smoothness characteristic of a steam generated unit and with all load shocks, characteristic in cable, gears and chains, eliminated. The engine had to act as a steam throttle for the entire torque speed range. The overall dimensions had to be held to the minimum width, height and length. The total weight was restricted to 10,000 pounds for each hoist of which each unit part, consisting of not more than four parts, should not exceed 3300 pounds each. An essential specification was that the complete hoist be assembled and disassembled into four parts in one and a half hours.

The design, taking the sacrifice of weight and other normal safety factors into consideration, required the very finest materials in construction to assure 100 percent performance. The officer's closing statement

(Continued on page 18)

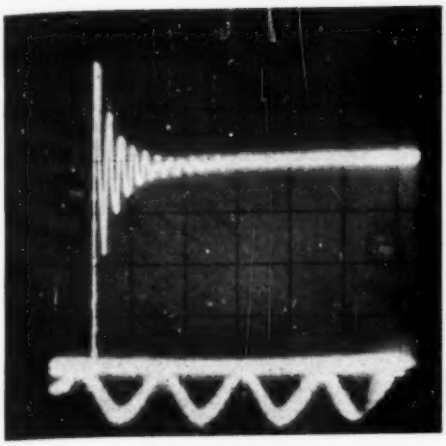


Fig. 1a

Fig. 1. Photographs of pressure curves produced on the screen of the cathode ray tube during impulse testing. Each photograph is a composite, since it represents graphically the pressure (vertical or "Y") beam deflection, a second exposure to record the time or sine wave trace and a third exposure to establish a zero pressure line across the film. In Figure 1a total "X" represents one second, in Figure 1b total "X" represents 0.1 second.

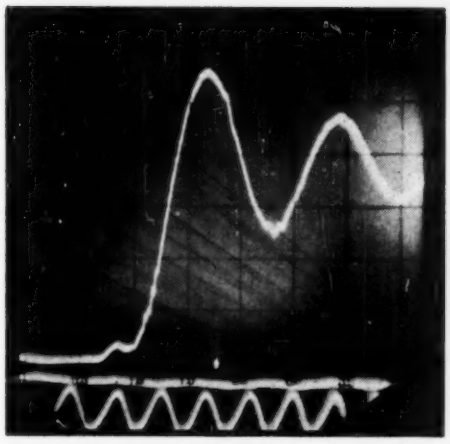


Fig. 1b

DETECTIVES AT WORK

The shock pressure problem

Procedure and analysis of the measurement of impulse or shock pressure phenomena in hydraulic systems by controlling the traces of a cathode ray beam on an oscilliscope screen.

By E. A. NIELSEN
Assistant Professor of Engineering
University of Michigan

THE PROBLEM of measuring transient pressures—high velocity impulse or shock pressures in hydraulic systems—has been handled in many different ways with varied degrees of success. It is important in designing components of hydraulic systems, particularly of transmission and control elements, to know what service to expect under the most severe operating conditions.

Accurate quantitative data has generally been obtained only in important research work and in special studies by careful use of extensive electronic equipment necessarily set up and operated by technical instrument personnel. Such equipment is characteristic of permanently installed laboratory apparatus. It offered practically nothing to the field service man.

Impulse or shock pressure testing has been used for pressure observations in hydraulic systems of aircraft, machine tools, presses, grading and mining machinery and other special equipment.

Prior to two years ago the testing and measurement of impulse pressures was somewhat slow, difficult and costly.

Measure Peak Surge Pressures

The test problem was to measure the peak surge pressure obtained upon application of each impulse cycle. Further, in order to meet exacting specifications, e. g., the impulse tests specified by the Army and Navy in qualifying tube fittings for use on service aircraft, it is imperative that the pressure phenomena induced be shown and recorded by means of some type of high speed electronic pressure indicating device. Pressure gauges are not fast or accurate enough to indicate or record the actual pressure conditions present, the duration of the peak surge pressure in any one impulse cycle being only approximately 0.02 sec.

These peak surge pressures are now being recorded by means of an indicator unit which is designed to function as a high speed electronic pressure phenomena analyzer.

Figure 2 shows an impulse test of flexible hose assemblies being made. Six high pressure hoses with 180 degree bends are being impulsed from a high pressure manifold. A hydraulic pressure pick-up, fitted into the end of the manifold is connected to the indicator in which the pressure signals are converted to electrical signals, which in turn are amplified and projected on the screen of a cathode ray tube as a graphical curve.

The impulse tester is operated hydraulically. Figure 3 shows the essential elements of the machine schematically. Hydraulic oil, maintained at 60 F by a cooler within reservoir A, is supplied by constant

displacement pump B, whose discharge pressure is determined by adjustment of relief valve C. The pump discharge is directed to an intensifier D, which boosts the pressure in a ratio of three to one. The high pressure fluid is piped from the intensifier through a four-way sliding valve F, into the manifold G, to which test samples are coupled.

A pressure impulse results each time the valve operates to direct high pressure fluid into the pressure manifold. The shock pressure is attributed to the high pressure fluid at the inlet port of the valve rushing into the manifold in an endeavor to equalize pressures in the system. The fluid gains considerable velocity, therefore the momentum imparted to the fluid is large. The energy of momentum of the fluid is quickly changed to pressure energy as the rate of flow drops and the manifold pressure rises rapidly.

Control of Shock Peaks

The shock pressures thus produced may reach values several times greater than the static system pressure, the peak pressure reached depending greatly on the rate of flow through the valve. Control of the impulse of shock peaks is therefore managed by regulation of the rate of opening of the four-way valve. To achieve this, the four-way valve is hydraulically actuated, and the rate of opening is determined by the hydraulic pressure in the actuating lines. Control of this pressure is accomplished by the use of manually adjusted flow control valve H. To produce repetitive impulses, cyclic reversal of hydraulic flow in the actuating lines is provided by a pilot valve I, which is driven by a motor-eccentric mechanism at the rate of 35 cycles per minute. For measurement of the pressure produced, a pressure pick-up element J, installed on the manifold, is coupled to the indicator K.

The pressure pick-up element consists of two electrical resistance coils, one of which is wound under tension around a thin walled tube with an open end coupled to the fluid chamber whose pressure is to be measured. Pressure increases in the system cause the thin walled tube to expand, stretching the wire and so increasing its electrical resistance. The second coil, identical with the first, is wound around a solid portion of metal at the end of the tube and is not subjected to pressure changes. This is done to provide temperature compensation since the temperature changes also affect the resistance of the coils.

Together, these coils form two legs of a Wheatstone bridge circuit. The net effect is that the electrical current changes produced in the bridge circuit are due only to the expansion and contraction of the tube as the pressure within it changes. The regulated direct current which is sent through the pick-up is amplified in the indicator and transmitted to the deflection plates of a standard 5-inch cathode ray tube.

The current changes will then cause a vertical or "Y" deflection of the cathode tube electronic beam directly proportional to the change in pressure. At the same time, the beam is moving at a uniform rate in the horizontal or "X" direction, so that the observed result on the screen of the cathode ray tube is a pressure curve graph in which "Y" represents pressure and "X" represents time.

Photographs of Beam Travel

Photographs of the beam travel are possible by means of a photographic attachment connected to the front of the indicator which houses the cathode ray tube screen. Since the camera has no shutter, the cathode ray beam must be controlled as to its appearance on the screen and its position when it does appear.

When beam control is desired, it is handled through a reset device, which allows only one trace of the beam across the screen when the reset button is depressed. This eliminates the possibility of double exposure.

Positioning of any part or the whole of a pressure phenomena on the screen is controlled by means of an external circuit which energizes the cathode ray beam by means of a microswitch. The microswitch is clamped to the device being analyzed in such a manner to insure actuation at the instant the trace of the pressure phenomena is desired. The microswitch is connected to the external circuit of the indicator by means of a two wire electrical connection.

In order to establish the unit of time on the "X" axis of the cathode ray beam trace, another exposure is made on the same film by depressing the timing button on the indicator panel. This action produces a sine wave trace at the bottom of the film, the frequency of which is set by the speed of the trace being used.

A third exposure is made to establish a zero pressure line across the film by depressing the calibrate button on the indicator panel at a time when no pressure is present in the hydraulic system being analyzed.

The unit of pressure of the "Y" axis is set by means of a control knob on the panel of the indicator.

With these three traces recorded on the film—the zero pressure trace, the timing trace and the pressure phenomena trace—a complete analysis of the pressure phenomena in its relation to time is possible. Rates of pressure rise may be readily calculated, peak surge pressures accurately determined and in the case of field testing, features important in the design and maintenance of the system can be analyzed.

Figure 1 reproduces actual photographs of pressure curves produced on the screen of the cathode ray tube during impulse testing. These photographs are reproduced in reduced scale, the true screen size is 3½ by 3½ inches, the numbers on both the "X" and "Y" scales representing inches. For these pictures, the sensitivity of the "Y" deflection has been adjusted so that one inch on the "Y" scale represents a pressure of 1500 psi.

In figure 1a the total "X" represents a time of one second. In analyzing this photograph, it may be seen that upon impulse the manifold pressure rose with exceeding rapidity from atmospheric to a peak of 4500 psi (three inches at 1500 psi). Thus the impulse tester was set to produce pressure peaks of 150 percent of the operating pressure.

Reading the Photographs

Figure 1b is the same as figure 1a except that the "X" time is 0.1 second instead of 1.0 second. A small

Data on the photographs of beam travel and on field testing has been furnished by F. W. Cowdrey, design engineer, Parker Appliance Company.

REMEMBER PEARL HARBOR

(Continued from page 16)

summed up the urgency—"We do not have a second chance to come back—*It's now or never.*"

Six Wheels, Inc., accepted the challenge and were given the go-ahead on three units.

Experience gained with these units made the delivery of the first twelve hoists at Pearl Harbor possible in record time.

Although the story is almost forgotten, the torque converter was one of the first jobs that went to war.

variation in the peak pressure is disregarded. Since the "X" scale is now expanded ten times, only the first portion of the curve in figure 1a is portrayed in figure 1b. From this curve, it is readily computed that the rate of pressure rise at impulse is about 320,000 psi per second and that the frequency of the shock wave is 40 cps.

The zero pressure lines and sine curves shown in both figures 1a and 1b establish a pressure reference and time reference, respectively. While photographs are very easily made, they are seldom used in impulse testing work. The test operator merely views the screen of the instrument throughout the testing so that he may adjust and maintain the impulse machine at the desired peak pressure setting at all times.

Pressure record photographs are valuable, however, in field testing, where permanent records of pressure phenomena are desirable for reference and study.

For field testing the indicator may be used as a complete testing apparatus. It is portable and can be operated by one man who can set up the equipment and be ready to take photographs in one hour or less. The indicator may be used with various types of electrical pick-ups wherever a high grade direct current coupled oscilliscope is required. Its primary use, however, is for determining and recording pressure phenomena in hydraulic installations which have pressure ranges from 0 to 15,000 psi and transient frequencies from 0 to 20,000 cycles per second.

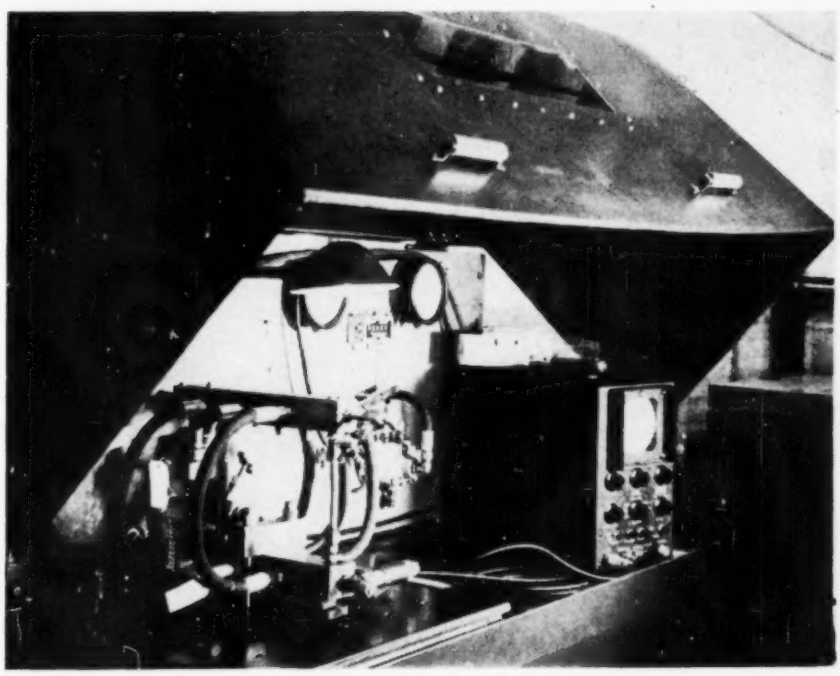
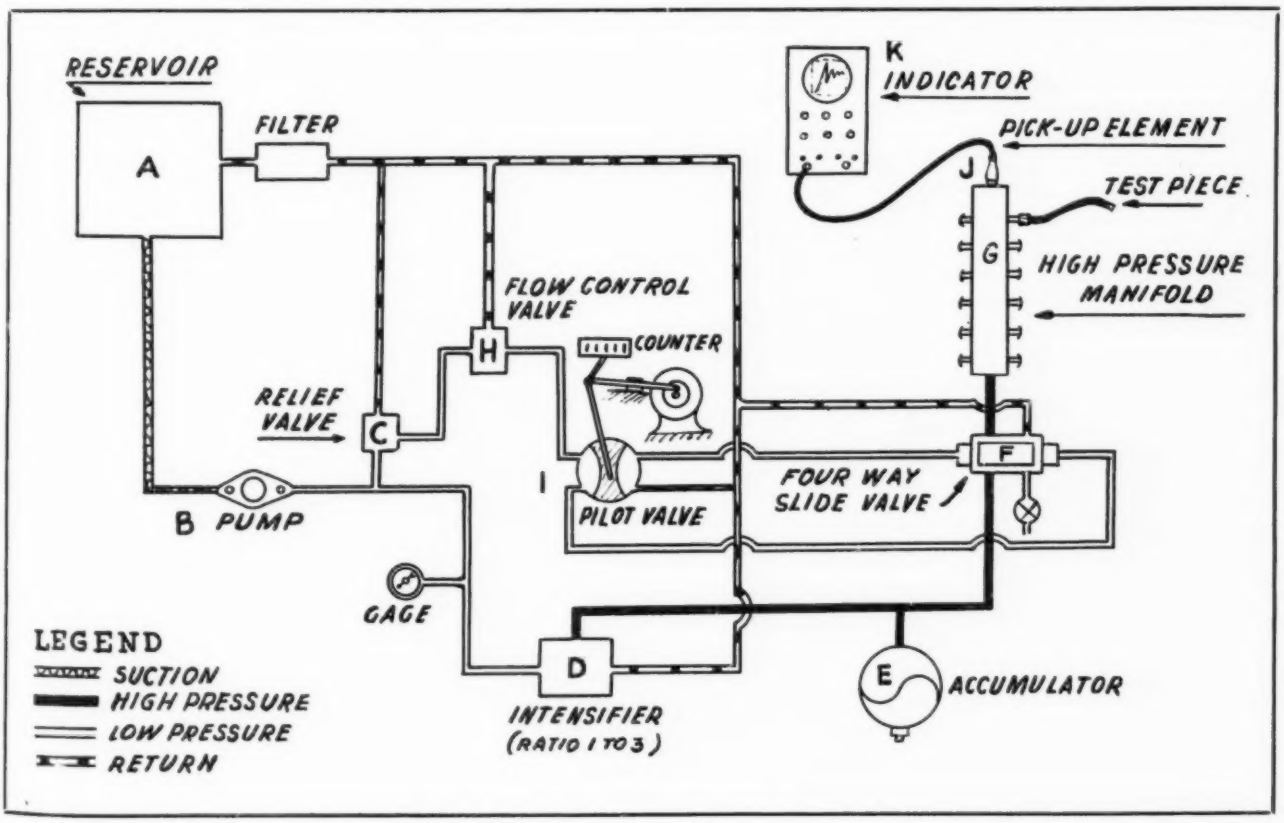
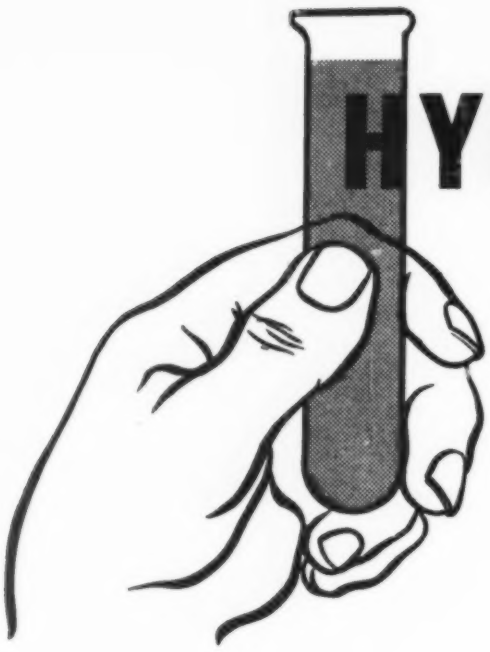


Fig. 2. The impulse test set up for destructive testing of six high pressure hoses with 180 degree bends. A pressure pick-up connects the manifold to the indicator unit.

Fig. 3. A schematic diagram of the impulsing test shown in Figure 2.





HYDRAULIC OILS

This is the first of a series on the properties, selection and use of hydraulic oils. Articles on specific problems will be contributed by leading authorities at regular intervals.

THE SELECTION of the proper hydraulic oil for a given application is extremely important. A proper selection cannot always be made solely on the basis of specifications. Such factors as expected periods of activity and idleness, severity of service, exposure of the equipment and the oil to contaminants, efficiency of the means of filtering, the range of heats developed at critical points in the system and the inspection and oil replacement practices of the user may well be of at least equal importance if the hydraulic systems are to be maintained in good, efficient operating condition.

Oil suppliers do not agree on any given group of specifications in their recommendations of an oil for a given application. However, there are service properties that all agree are essential. These will be discussed briefly, after which miscellaneous secondary specifications will be treated.

Viscosity

The first, and most important, property of an hydraulic oil is viscosity. Viscosity is a measure of resistance to flow. A number of grades of oil are supplied to meet the requirements of pump manufacturers, whose equipment, due to design features, operates most efficiently with an oil of a specified viscosity. The range of viscosities recommended by each pump manufacturer should be followed in each case.

The unit of viscosity in general use by the oil industry is the Saybolt Universal Seconds (SSU), a measure of viscosity as determined by the use of the standard Saybolt Viscosimeter.

The Saybolt Viscosimeter is an apparatus in which the flow of a petroleum product or lubricant at a predetermined temperature can be accurately controlled and timed. The time-flow relationship is a measure of viscosity and is designated in Saybolt Universal Seconds or SSU.

A GOOD HYDRAULIC OIL . . .

1. **Possesses the proper viscosity to maintain efficient working pressures;**
2. **Has a viscosity index high enough to resist appreciable changes in fluidity under temperature changes;**
3. **Possesses good inherent resistance to chemical changes, i. e., it is stable and remains stable during normal service periods;**
4. **Has the ability to provide adequate lubrication on all moving parts.**

A HYDRAULIC OIL NOT WELL SELECTED . . .

1. **Permits the deposit of gums and sludges on working parts;**
2. **Has a corrosive effect on metallic surfaces of the system;**
3. **Does not resist contamination from moisture, cutting fluids, etc., thereby reducing the service life;**
4. **May reduce mechanical efficiency, decrease production and increase maintenance cost.**

The majority of hydraulic systems operate most efficiently with oils possessing the following viscosity ranges: 135 to 165 SSU; 185 to 230 SSU and 275 to 315 SSU.

Viscosity Index (VI), the ability of an oil to resist changes in viscosity when subjected to changes in temperature, is also an important index to the suitability of an oil for a given use. The Viscosity Index is an arbitrary number established by ASTM definition to indicate the effect of change of temperature on the viscosity of an oil. By the commonly used Dean & Davis method, mineral oils may have a viscosity index from a minus zero to 120. A high viscosity index indicates that less change occurs in the viscosity of an oil with changes in temperature. Most hydraulic pump manufacturers specify oils having VI's of 75 or over.

The effect of temperature on the viscosity characteristics of 100 VI hydraulic oils can be determined from the ASTM viscosity-temperature charts.

Oxidation Stability

Chemical stability or oxidation stability is also a very important factor in the selection of an hydraulic oil. Oxidation stability, as it is more frequently called by oil suppliers, is the resistance that an oil offers to chemical changes induced by temperature and the presence of catalysts. Air or oxygen, in addition to introducing foaming, forms sludge and acidic compounds through a chain

reaction. When water is present, the chain reaction is accelerated. Hydraulic oils are compounds of complex structure and when air, water, metallic and other foreign matter are introduced, new and more complex compounds are formed; elevated temperatures and high pressures accelerate the process of breakdown. The oil may become progressively darker in color, of higher viscosity and more acid.

Considerable laboratory work has been done in devising tests to predict the stability of an oil.

Accelerated oxidation tests are commonly used for classifying hydraulic oils. The Indiana test or the Continental oxidation test, which is a modification of the Indiana test, is usually chosen. The Sligh oxidation test, once extensively used, is now most useful in refinery control.

Many hydraulic oils on the market today contain oxidation inhibitors which further enhance their inherent oxidation resistance.

Demulsibility

Demulsibility is the ability of an oil to separate out of an oil-water emulsion quickly and completely. High quality hydraulic oils are water resistant and possess good demulsibility. Emulsions when formed, may vary from thin, slippery to heavy, gummy deposits, depending on the type of oil, its service age, the nature and quantity of contaminants present and on the operating characteristics of the system.

Three main types of emulsion tests are in general use. There is general agreement that the test methods are too sensitive for practical use. Small differences in surface cleanness, the presence of even minute quantities of contaminants other than moisture and the use of additives may result in misleading test results.

Film Strength and Lubricity

The lubricating value of an oil depends on its ability to form efficient, low friction surfaces on the moving parts of the system. This is related to its lubricity or oiliness properties. Film strength is a measurable property, but it is not always included in the specifications because the lubrication function of an hydraulic oil has generally been considered as secondary. Adequate film strength minimizes the wear of parts moving at close tolerances, e. g., the wear on vanes and on the annular rings of vane pumps, the mating teeth of

(Continued on page 44)

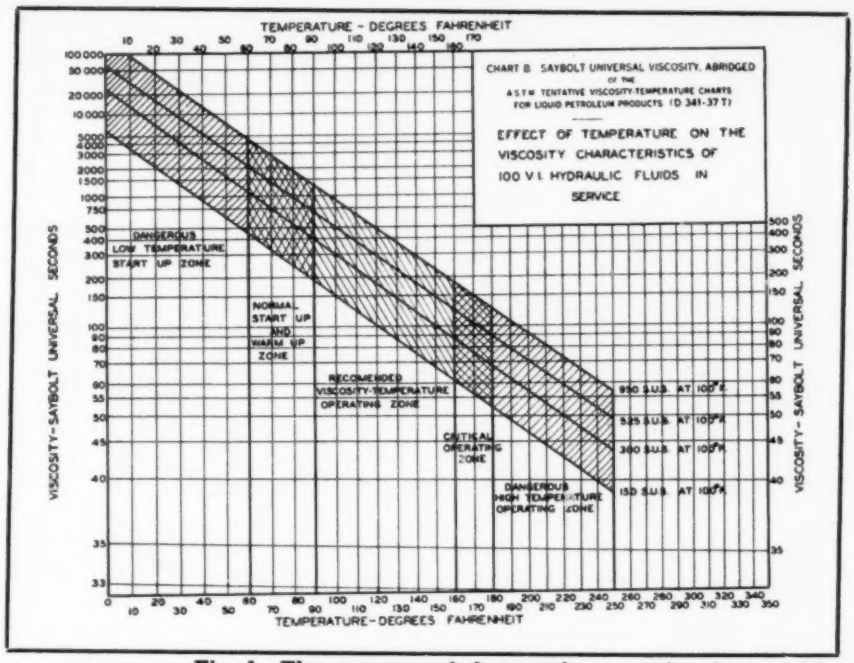

TEMPERATURE - DEGREES FAHRENHEIT
CHART B SAYBOLT UNIVERSAL VISCOSITY, ABRIDGED OF THE ASTM TENTATIVE VISCOSITY-TEMPERATURE CHARTS FOR LIQUID PETROLEUM PRODUCTS (D 341-37 T)
EFFECT OF TEMPERATURE ON THE VISCOSITY CHARACTERISTICS OF 100 V.I. HYDRAULIC FLUIDS IN SERVICE
DANGEROUS LOW TEMPERATURE START UP ZONE
NORMAL START UP AND WARM UP ZONE
RECOMMENDED VISCOSITY-TEMPERATURE OPERATING ZONE
CRITICAL OPERATING ZONE
DANGEROUS HIGH TEMPERATURE OPERATING ZONE
950 S.U.S. AT 100° F.
525 S.U.S. AT 100° F.
300 S.U.S. AT 100° F.
150 S.U.S. AT 100° F.
VISCOSITY - SAYBOLT UNIVERSAL SECONDS
VISCOSITY - SAYBOLT UNIVERSAL SECONDS
TEMPERATURE - DEGREES FAHRENHEIT

Fig. 1. The recommended operating zone has been established on the basis of optimum pump efficiency. A selection of an oil with a recommended viscosity at operating temperatures can be made. If the pump manufacturer recommends a 150 SSU, 100 VI oil for operation at 100 F and the system operates at 150 F, a heavier oil is indicated. This may be selected by using the chart.

Fig. 2. The Saybolt Universal Viscosimeter is used to establish an arbitrary time unit as an index of viscosity. The oil is heated, usually to 100 F and is permitted to flow through a standardized oil tube into a receiving flask of 60 cubic centimeter capacity. The time for this flow is accurately timed.

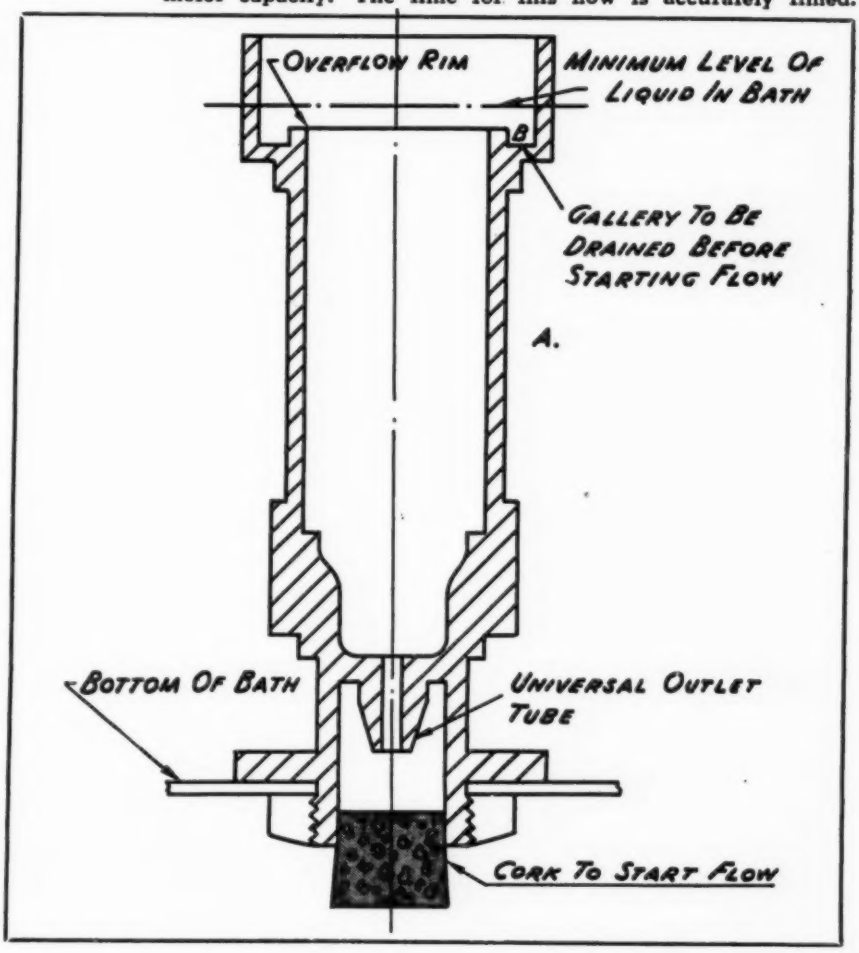


Fig. 1. The front of the flash welder. The operator is shown manually controlling the approach or advance phase of the cycle.

ACCUMULATOR APPLICATIONS TO WELDING EQUIPMENT

The employment of inherent accumulator advantages by a welding equipment manufacturer to gain important design and cost advantages.

By H. A. VANDER KAAY
Hydraulic Engineer
Progressive Welder Company

THE USE of pressure oil accumulators on resistance welding equipment has the same general purpose as the probable majority of other accumulator applications—to permit a reduction in size of the fluid power supply.

The size or necessary capacity of hydraulic systems associated with multi-spot or flash welding installations is frequently determined by the volumetric requirements of the electrode operating cylinders or "guns". In some of these cases, the power demand of any other hydraulic function will be a minor fraction of that desired for the gun movements. In other cases, the gun operation is the only function that requires hydraulic power.

A group of press type multi-spot welders recently manufactured may serve as an example. The circuit diagram is that of a setup for 52 electrodes. Other presses in this group vary only in the design of fixtures and the number and disposition of electrodes.

The welding machines we will discuss are of the universal high production type for adaptability to a wide range of applications without major alterations. Each unit is self contained; one end of the one-piece frame houses the transformer and regulator, constructed as a removable unit; the other end contains a unit type hydraulic power unit. This unit is also removable for inspection and maintenance without disassembly. All pressure gages, sight gage, pressure relief valves and controls are conveniently grouped in a "hydraulic adjustment station" for the operator.

Three Functions Hydraulic

Three major functions of the machines—platen traverse, platen locking and gun actuation—utilize hydraulic power.

The diagram schematically illustrates the components of a typical hydraulic system for a multi-spot welding cycle. The operational sequences of the cycle are:

(1) Load Work Pieces
(2) Raise Platen
(3) Lock Platen
(4) Advance Electrodes
(5) Perform Weld
(6) Retract Electrodes
(7) Unlock Platen
(8) Lower Platen
(9) Unload Assembled Work Pieces

The functions that require the relatively greater hydraulic power rates are the platen and the electrode movements. Assuming conventional speeds for these functions, a supply rate of twelve gallons per minute becomes necessary for the platen actuation, while an approximate rate of thirty-two gallons per minute is momentarily required to advance the fifty-two electrodes in one-half second.

By comparison, the average demand for the operation of the electrodes is 0.27 gallons per machine cycle or 1.16 gallons per minute with a fourteen second machine cycle.

As indicated in the hydraulic diagram the use of the accumulator for the operation of the electrode cylinders permits the selection of hydraulic pump, driving motor, relief valve and reservoir size to be based on the maximum platen cylinder power requirements.

This power is ample for the function of recharging the accumulator.

Type of Accumulator

The type of accumulator used—a nitrogen filled bladder enclosed in the body of the accumulator—eliminates most of the undesirable features of older spring-loaded, gravity, free gas, air-loaded piston and diaphragm types. Bladder type accumulators are relatively small, effectively sealed, require no alignment, eliminate oil-gas contamination and piston packing. Maintenance is reduced to occasional recharging of the bladder.

The flexibility of the power supply is a major factor in the ability of the machine to do a wide range of operations. The flexibility also permits the use of identical hydraulic power equipment on all of the machines in the series.

The hydraulic operating systems are available in manual or selective control, the latter permitting manual, semi-automatic or full automatic operation. Manual control permits the operator to control all the stages of the welding cycle from one position.

Semi-automatic control, when it is desirable, can be secured on automatically operated welders by dropping out one of the automatic circuits. For example, it is a usual practice when welding heavy sections to permit the skilled operator to control the initial heating of the work and the preliminary flashing by "feel". In this case the automatic feed control for approach may be turned off. When the platen reaches the desired start of automatic flash, an automatic cam control takes over and completes the cycle.

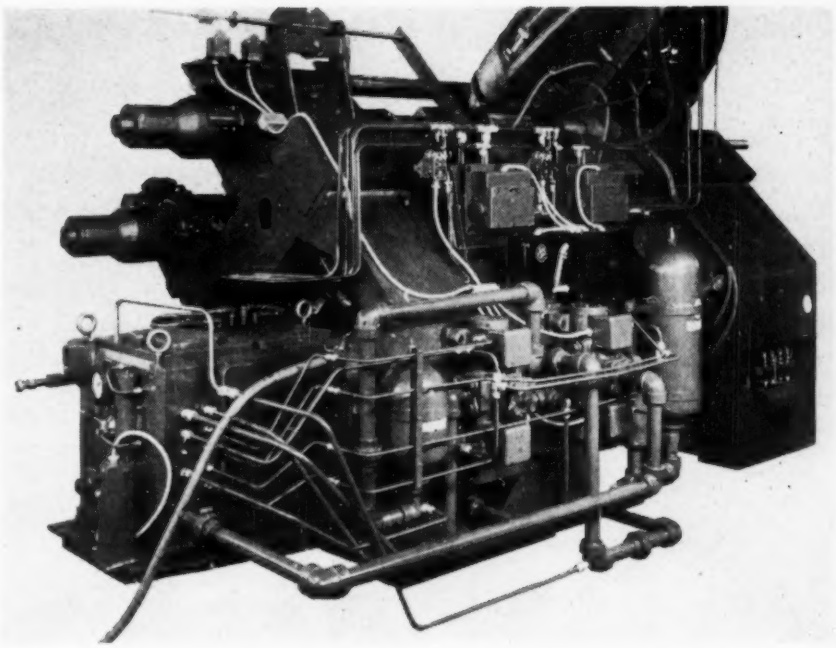
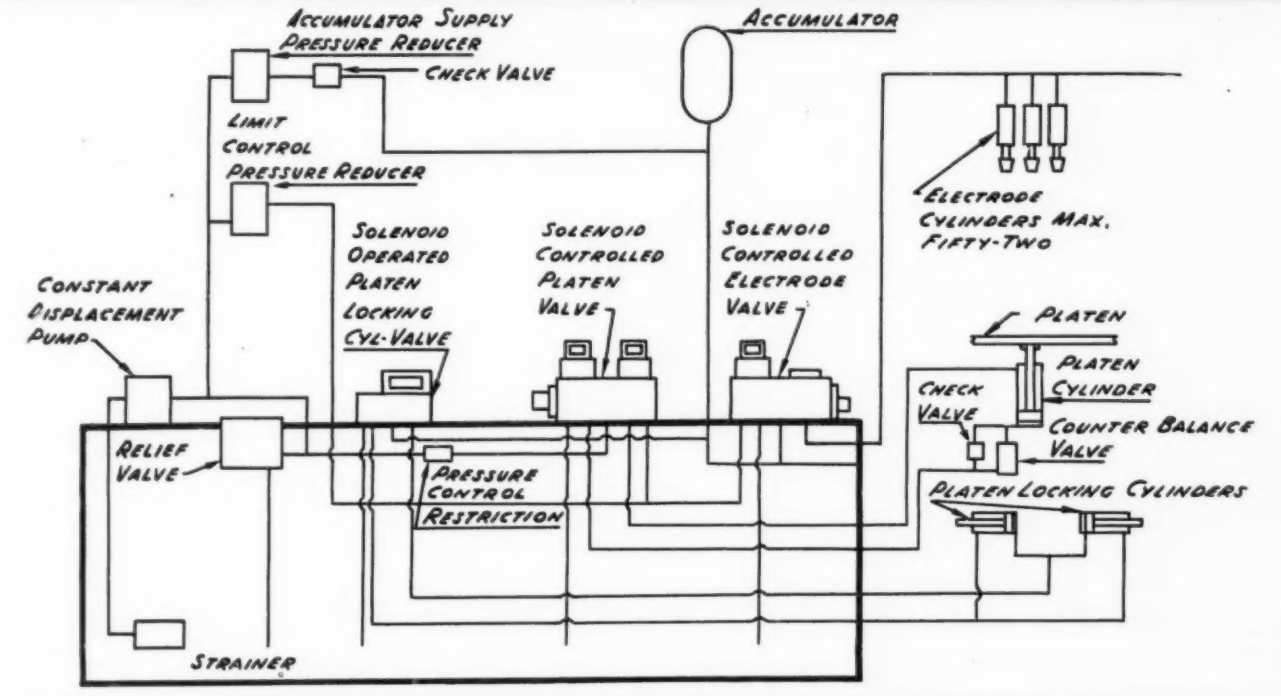


Fig. 2. Shows the back of the same machine illustrated in Fig. 1. This is a 500 kva capacity unit set up for welding large diameter steel shafts. The machine is fully automatic and utilizes hydraulic power for platen traverse, clamping and upset.

In full automatic control the machine goes through the entire platen travel, flash and upset cycle automatically. The platen travel is ad-

(Continued on page 32)

Fig. 3. The accumulator in this system functions as a reserve of fluid power to operate the electrode opera[tor] cylinder advance. The platen cylinders, one for raising and lowering a[nd] two for locking and unlocking the platen, are operated by a solenoid controlled four-way valve. Electrode advance or gun actuation is by a solenoid controlled three-way valve. Both actuating valves shift hydraulically. The control pressure of these valves is maintained by a connection to a pressure reducer. The counter balance valve, right, functions as an overload or relief valve.



HYDRAULIC OPERATION FOR A ST

A high production, special processing machine into which are incorporated self-contained hydraulic systems in each of five stations, a motor driven hydraulic unit for indexing and a circuit for locking the machine table. Hydraulic actuation was selected to meet the critical demands of a high production manufacturer for safe and flexible automatic operation, full control from one position and long trouble-free service.

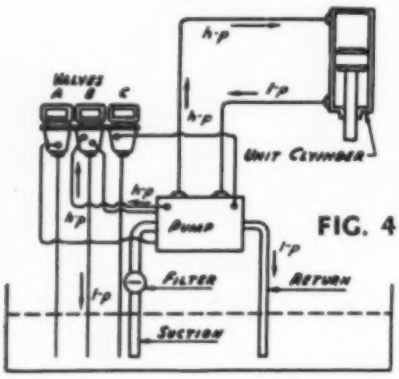


FIG. 4

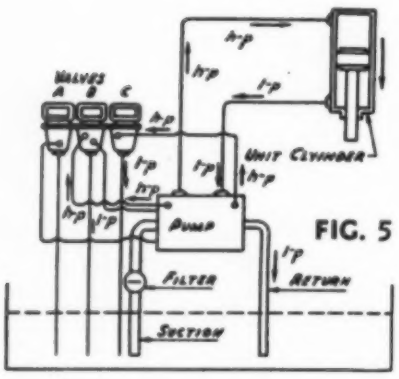


FIG. 5

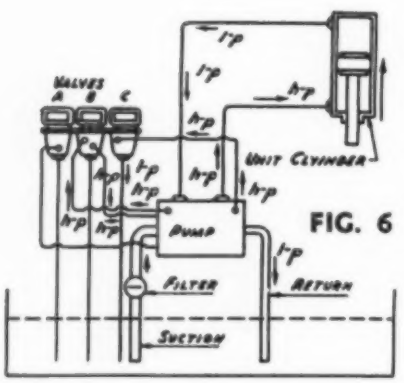


FIG. 6

THIS MACHINE as designed for Continental Motors by the Sommer & Adams Division, The Federal Machine and Welder Company, was tooled for drilling, reaming and counterboring Kaiser-Frazer engine connecting rods and caps. Each station handles four complete assemblies. Production of 240 complete units per hour is easily obtained at 80 percent efficiency.

Each station and the table index are push button controlled, the spindles being controlled for set-up purposes through manual controls on each station. However, the machine is basically designed for automatic cycling and continuous operation.

Each station is hydraulically powered by dual variable displacement pumps. The pumps are controlled by solenoid valves operated through limit switches located on the station. The circuit diagram gives details of the hydraulic installations.

Push buttons on the operator's control panel interlock with all motor controls so that in the event any one of the motors fails to run, the machine will not go into its sequence of operations. Relays and solenoids

DRILL UNIT CIRCUIT

Fig. 4. Tripping the positive index switch energizes solenoid operated valves "A" and "C." This actuates the valve to divert high volume oil to the drill unit head for rapid forward movement.

Fig. 5. When the head approaches the work the slow feed limit switch is actuated. The unit feeds to depth against a set stop. Valve "C" is de-energized, valve "A" delivering low volume working pressure oil for the feed stroke.

Fig. 6. A limit switch actuates the rapid reverse switch and energizes valves "A" and "B," reversing high volume oil within the pump to return the head. As the drill unit completes its return it trips a limit switch, de-energizes the triple solenoid, stopping the head motion.

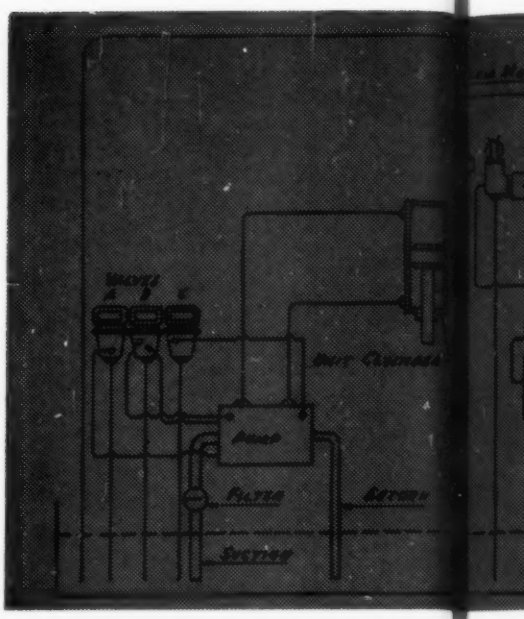
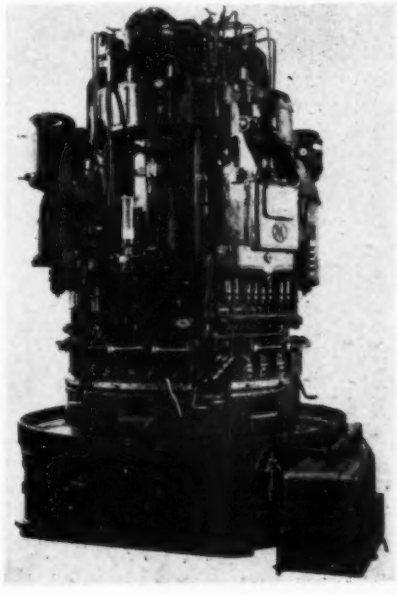
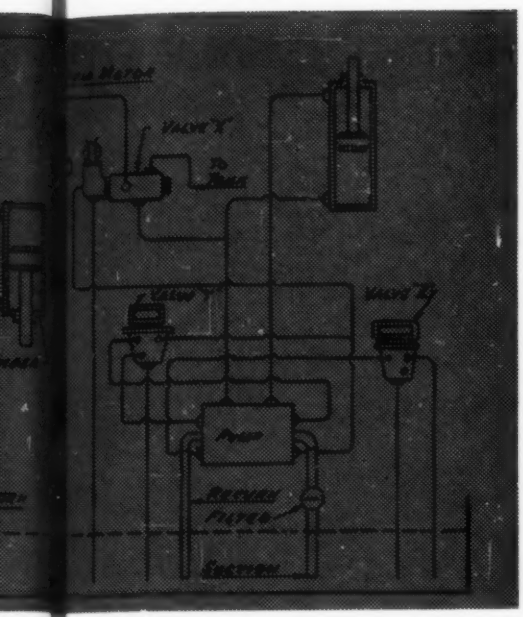


Fig. 1. Drill unit circuit (h… and i…

Fig. 2. Seven hydraulic circuits—self-contained units for each of the five stations and two for indexing and locking the table—are incorporated into this production machine.



STATION PRODUCTION MACHINE



and indexing circuit (right).

convert electrical energy to mechanical energy to actuate the units of the machine.

A cascade system is used to lubricate various parts of the working mechanisms, table bearings, lock pin and fluid motor drive by a motorized pump in the bed. The head unit ways have an automatic pressurized grease system.

The loading and unloading station, which is the sixth station on the machine, is convenient to the control panel so that the operator may, if necessary, hand index the table should any of the units become inoperative.

The machine is tooled for operations as listed in the box. However, a variety of drilling, reaming and counterboring operations are possible merely by changes in the tooling of the stations. Hydraulic and electrical controls interlock, insuring long tool life and the ability to meet exacting production schedules.

Fig. 3. The cap and connecting rod for which the machine was tooled.

LOCK PIN AND INDEXING CIRCUIT

Fig. 7. Depressing the cycle start button energizes solenoid "Y" which actuates a four-way valve in the pump, diverting the total capacity of the pump to the lock pin cylinder as the solenoid operated valve "X" blocks oil to the reservoir and fluid motor.

Fig. 8. Retracting the lock pin trips a limit switch energizing solenoid valves "X" and "Z". Valve "Z" dumps the 9 gpm low pressure oil while the retaining pressure 2 gpm pump continues to operate. Valve "X" allows delivery of oil to the indexing fluid motor, starting the power stroke. A cycle valve in the outlet line maintains back pressure preventing table overrun.

Fig. 9. After an initial 5° table movement, a limit switch is tripped, de-energizing valve "Z", adding 9 gpm and accelerating the table for 50° of rapid movement after which the valve is again energized by a limit switch, checking movement to the slow rate.

Fig. 10. A stop limit switch de-energizes valves "X", "Y" and "Z", completing the cycle. This shifts the valve, seating the lock pin. The low volume pump maintains pressure on the lock pin throughout the cycle, while the high volume pump is opened to the reservoir. After the lock pin has seated, depression of the positive index switch starts all drill units on their next cycle.

STATION OPERATIONS

Station 1—Counterbores the cap shoulder.

Station 2—Drills through the cap and spots the connecting rod with both pieces in position.

Station 3—Drills through the connecting rod, using a drill smaller than used in station 1.

Station 4—Core drills through both cap and connecting rod, automatically lining up both pieces and semi-finishing in the bores.

Station 5—Finish bores, removes .0003 to .0005 in stock, gives final line-up and reamed finish to the bores.

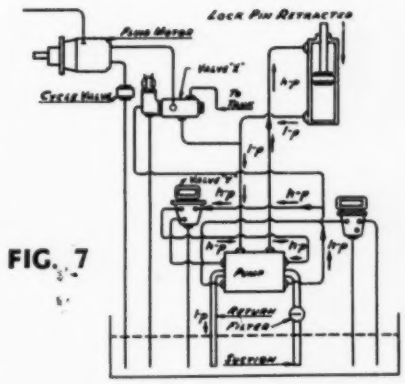


FIG. 7

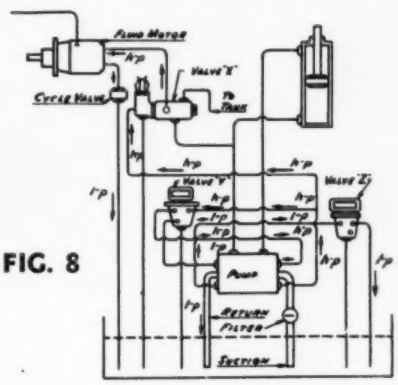


FIG. 8

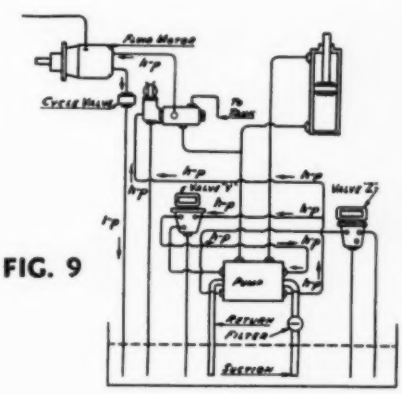


FIG. 9

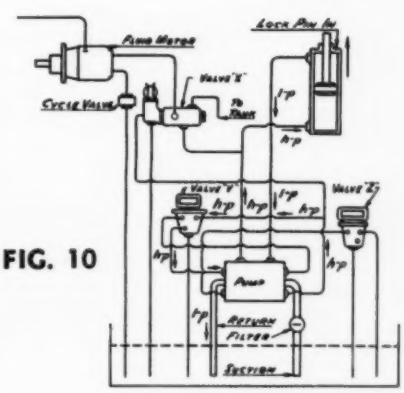


FIG. 10

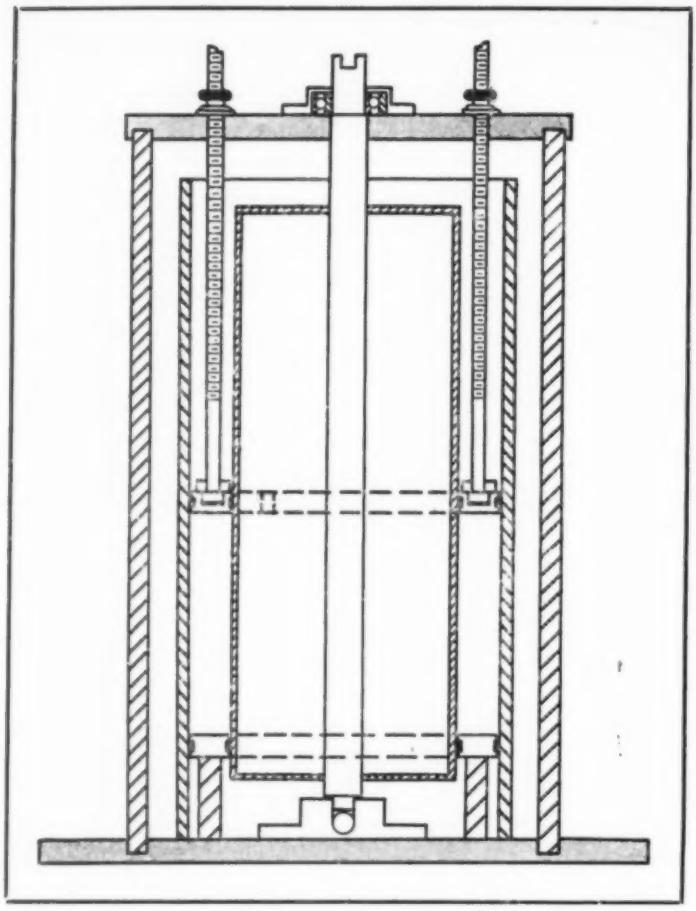


Fig. 1. The essential machine for demonstrating and observing vortex patterns.

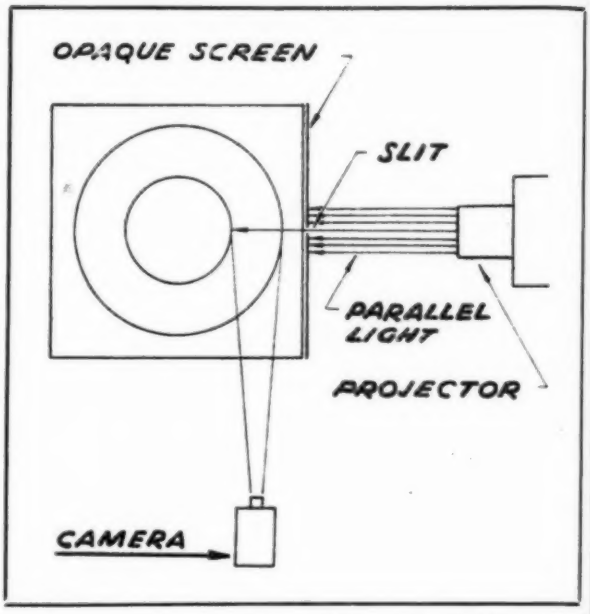


Fig. 2. Plan for lighting and photographing results of the test.

DESIGNING A HYDRAULIC SEAL

By W. W. HAGERTY
Department of Engineering Mechanics
University of Michigan

A method of hydraulically sealing a rotating shaft against leakage caused by an axial pressure gradient.

THE PURPOSE of this paper is to describe a method of sealing a rotating shaft against leakage caused by an axial pressure gradient. The sealing element was developed by applying principles of fluid mechanics to the problem. The result was a hydraulic seal which seals by hydraulic means. The essential features of this method will be described, but space will not permit the mechanical details, which are a part of the problem, to be treated completely.

The general theory of the fluid motion encountered will be presented first. Then the manner in which the theory is applied will be demonstrated and some general examples of seal design will be given.

Review of Theory of Fluid Motion in an Annulus

There are three modes of viscous fluid motion which can exist within an annulus whose inner wall rotates and whose outer wall remains stationary. These modes are:

1. Couette motion, a purely viscous, laminar flow which exists at low rotational speeds.
2. Taylor vortex motion, a stable form of motion which exists at intermediate speeds.
3. Turbulent motion, a highly irregular motion which exists at high speeds.

In the first of these modes, when the annulus has infinite axial length, the paths of all moving particles are simply circles concentric with the axis of rotation. When the annulus is of finite axial length, a rotary motion exists in the corners; but the central portion of the fluid moves

Based on a paper delivered at the Third Annual Meeting, National Conference on Industrial Hydraulics, Chicago, October 17, 1947.

with couette motion. In the third mode, that of turbulent motion, there is no regular pattern of any kind. Neither of these modes has any known application to sealing.

In the Taylor vortex motion, the fluid within the annulus divides itself into pairs of vortex rings in which particles of fluid rotate simultaneously both about the axis of the shaft and the core of the vortex.

If the outer wall of the annulus is also free to rotate, there are variations in the mode of motion; but these will not be considered, except to state that it is undesirable for sealing purposes to have the outer wall rotating.

Rayleigh, who did the first theoretical work on this problem, developed a criterion for the stability of an inviscid fluid in an annulus of infinite length in 1916. Briefly stated Rayleigh found that: when the product of the local fluid velocity, v, and the radial distance to the axis of the annulus, r, is a constant throughout the fluid, i. e., vr=constant, the pressure gradient of the fluid is in equilibrium with the centrifugal force; when the product, vr, decreases as r increases, the motion is unstable; and when the product, vr, increases with increasing r, the motion is sure to be stable.

From Rayleigh's work, we know that the motion of an inviscid fluid is always unstable when the inner wall of the annulus is rotating and the outer wall is stationary.

In a viscous fluid, small disturbances are damped out for certain values of the disturbance. In 1922, G. I. Taylor developed a criterion which shows the effect of viscosity on the disturbed motion in an annulus of infinite length. The results of Taylor's work may be digested as follows:

1. A formula which predicts the initial speed at which the fluid motion is unstable.

NOMENCLATURE

Couette motion is a true laminar motion in which every particle of fluid moves in a perfect circle about the axis of the cylinder at all times.

Taylor vortex motion is a stable form of motion in which each particle of fluid rotates within the annulus, while at the same time travelling around the cylinder in a path which, in general, is helical.

2. Assuming a periodic disturbance, Taylor found that the wave length of this disturbance is equal to $2a$ at the onset of instability.

3. Taylor determined that the streamlines of the disturbed mode of motion were symmetrical ring vortices of square cross section. All of the vortices were found to rotate about the axis of the annulus, and at the same time the vortices rotated about their individual cores as though geared together. In other words, adjacent vortices rotated in opposite directions with respect to their cores.

Experimental Apparatus

Since in practice all annuli are of finite length, an experimental apparatus was devised to determine the extent to which Taylor's criterion is valid for annuli of finite length, and to determine the effect of fixed end plates on the size, formation and stability of the vortex systems that are to be formed in the annulus.

Figure 1 is a drawing of the apparatus. In this machine the inner cylinder is driven by an infinitely variable speed drive with good control from 12 to 400 rpm. The outer fixed cylinder of the annulus is a lucite tube. A plexiglas box surrounds the tube and is filled with water to minimize optical distortion. The bottom plane ring of the annulus is fixed while the top ring can be adjusted.

Lighting was provided by a beam of parallel light which was directed through a slit as shown in Figure 2. A two-dimensional effect was obtained and the lighted area could then be viewed or photographed. The fluid motion was made evident by two methods. In the first, aluminum paint powder was suspended in the fluid. The powder was brightly lighted as the individual particles passed through the illuminated area. In the second method, a glycerine solution which exhibited high double refractive properties when in a state of shear was used in the annulus. The planes of equal shear then appeared as streamlines when polarized light was directed through the fluid. In this way the formation of the streamlines could be observed.

Results of Experimental Study

A number of interesting and useful results were obtained in the course of the experimental work. These will be described and the significance of each discussed very briefly:

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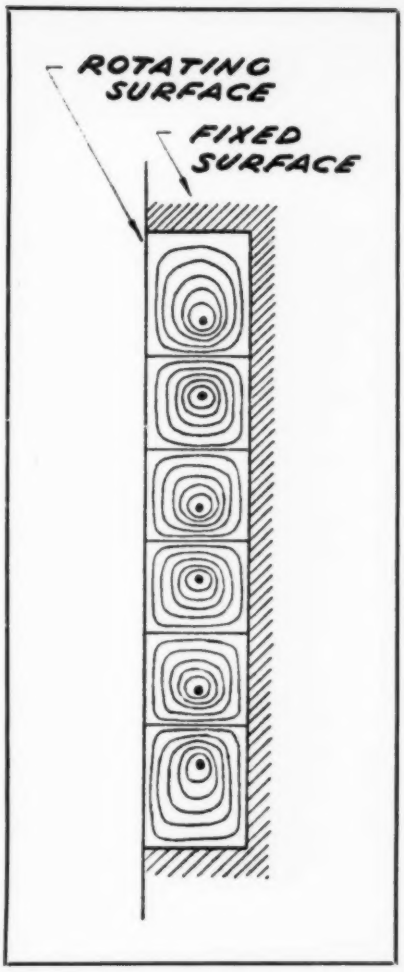
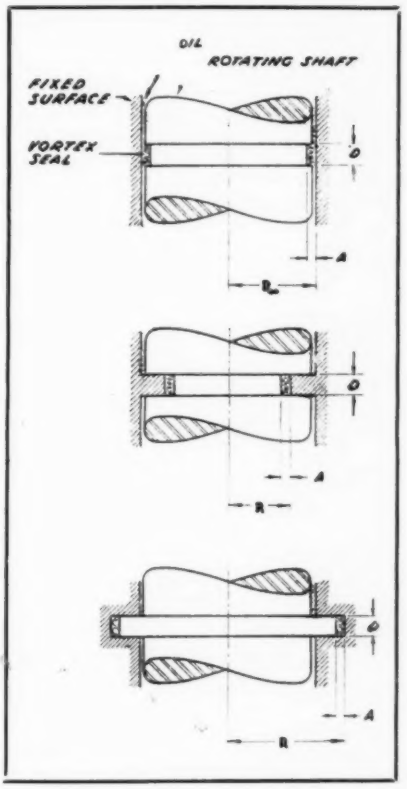
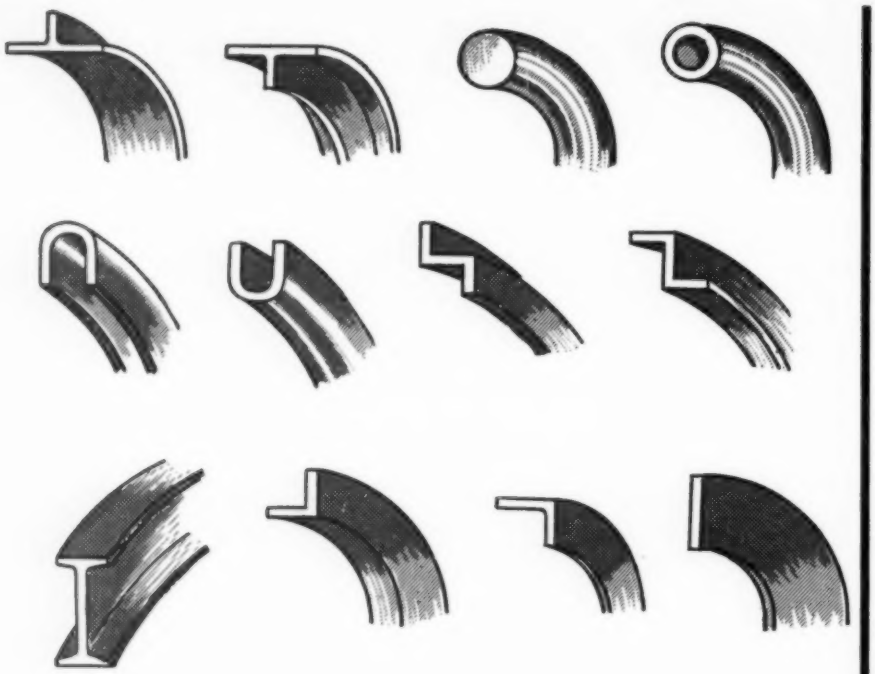


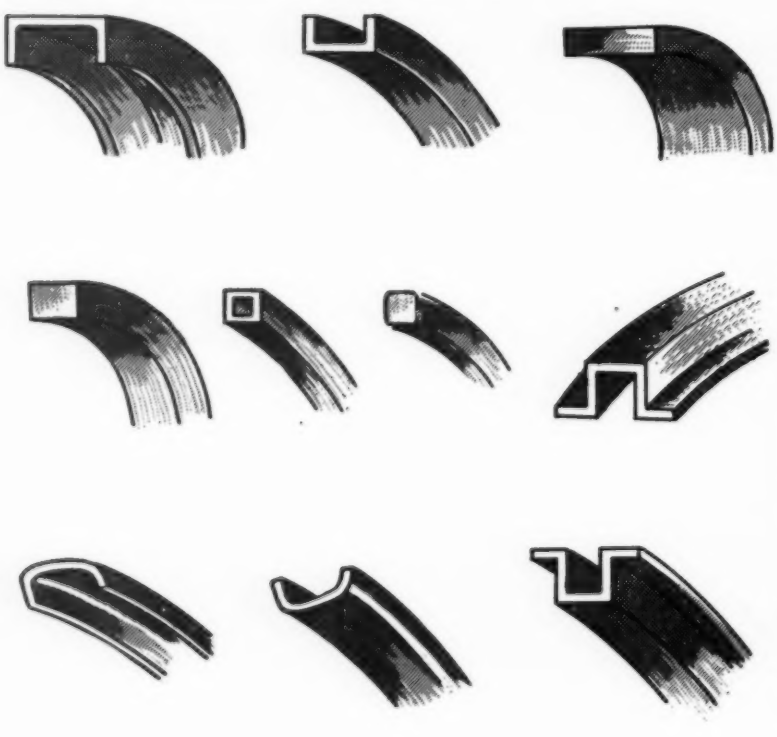
Fig. 3. A fully developed three-pair vortex system.

Fig. 4. Examples of seal design.





HYDRAULICS and the Tangent Bender



The application of hydraulic power to a production machine for edge and stretch bending and the radial forming of metal sheets, structurals and tubes smoothly and accurately with a minimum of labor and handling cost.

By LEE B. GREEN
Consulting Engineer
Struthers Wells Corporation

THE Tangent Bender is a basic production machine designed to bend sheet metal and to form rounded corners in a single operation. This is accomplished by wrapping a ram-type rocker plate die around a radius forming die against which the stock to be formed is clamped. The power arm of the machine is a swinging wing assembly to which the rocker plate is attached by a rack and pinion. In the loading position the rocker plate is horizontal and acts as a female die directly or as a base platen for the die fixture. A heavy spring on the outer half of the power arm is adjustable and fits against a bearing block supporting the pressure roll. The rear end of the power cylinder is anchored on a clevis mount against the rear base of the machine, the front end is similarly mounted on a projection of the bearing block housing at the approximate center of the power arm.

The Tangent Bender was first, and still is, widely used for forming shells of refrigerator cabinets. Other production uses include washing machines, electric stoves, space heaters, vending machines, tubular chair frames, camera and small appliance bodies.

When originally introduced the machines were air cylinder operated. These units did, and still do, credible work. However, these machines had some limitations which were troublesome on some classes of work.

Production Difficulties

The application of hydraulic power to the machine was the result of an effort to find a power source that

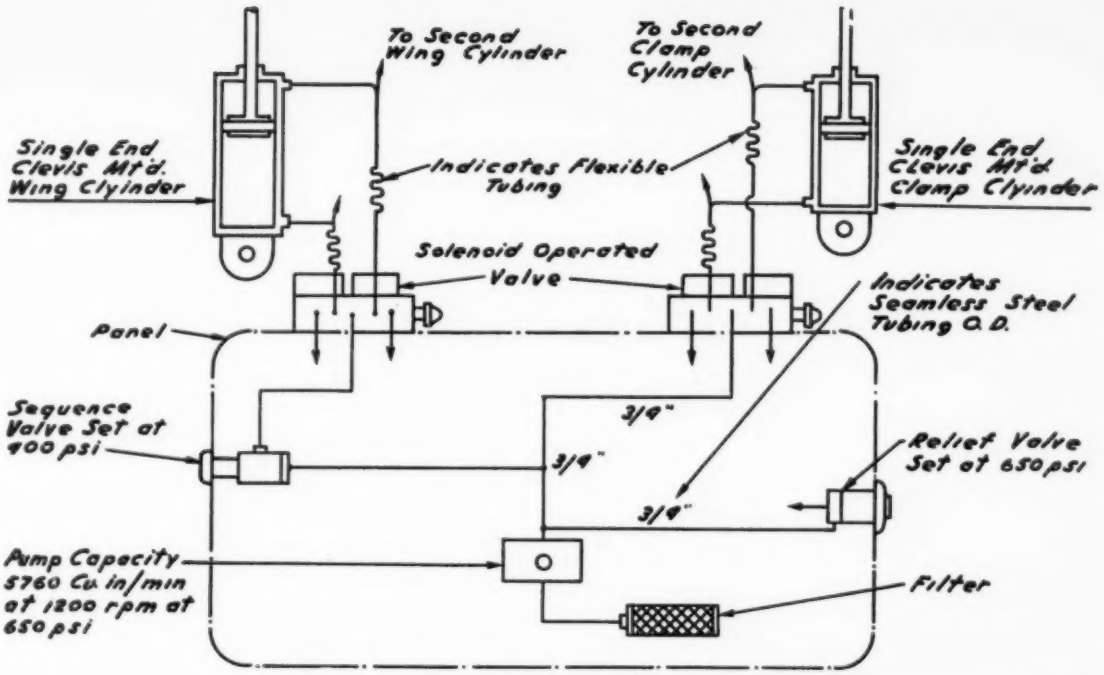


Fig. 1. The hydraulic circuit of the basis single wing tangent bender. Operation is by 4-way valves solenoid operated. A sequence valve completes the cycling control. Note that all branch lines have sections of flexible tubing.

would correct and compensate for the commonly encountered production difficulties. The first difficulty was the interruption in production due to uneven power flow. The second problem arose from the need for greater power to form heavier sheets. A third difficulty was due to the fact that variations in the thicknesses of commerical sheets required sorting and interruptions in production to adjust the machine.

On heavy duty jobs cylinders had a tendency to pause until the air pressure could build up sufficiently to overcome the resistance of the metal sheets. When pressure did build up, the cylinders jumped ahead, resulting in a wrinkling or "orange peel" effect on the finished work. These irregularities, when severe, caused rejection. The salvagable work required considerable hand finishing.

The power source for air operation was often a problem. Plants with central station air facilities seldom have ample power for cylinder requirements. Plants without such systems or with a heavily loaded system have the problem of providing a separate air pressure system of suitable capacity.

The variation in the thicknesses of commercial sheets is now much greater than pre-war due to a number of reasons. This made the sorting of sheets into groups of similar thicknesses an extra operation which is slow and costly when hand sorted. In addition, frequent stopping and

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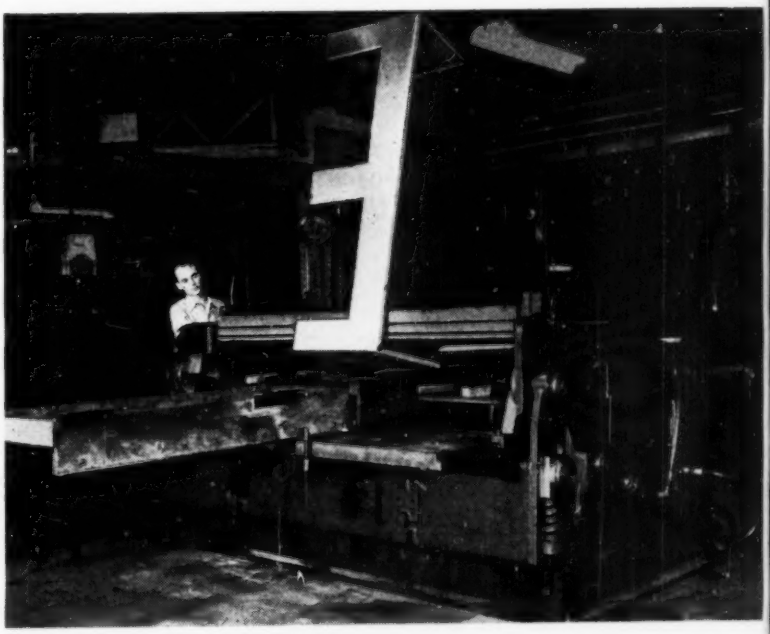


Fig. 2. The machine illustrated on the cover is shown here at the end of its cycle. The power cylinder has fully retracted, the power arm assembly turned through a 90 degree angle bringing the rocker plate on which the work is mounted on a fixture to a horizontal position. The unloading may be manual or by overhead conveyor.

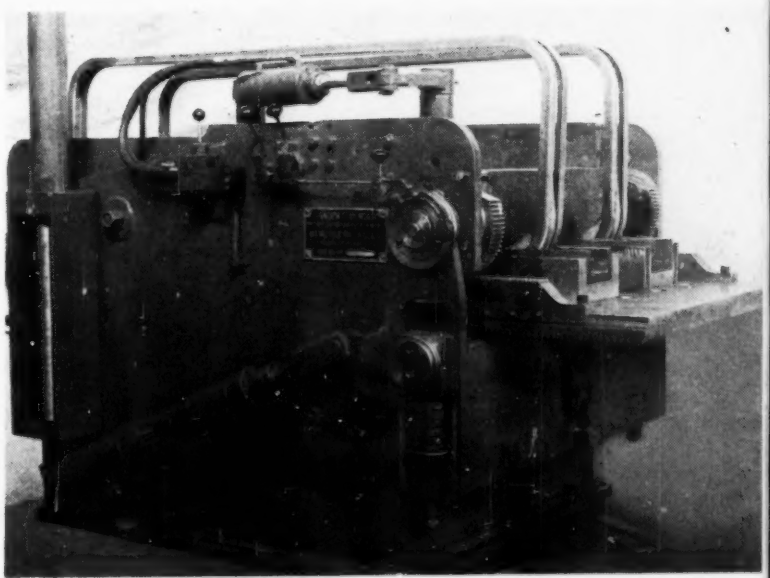


Fig. 3. A single wing Tangent Bender from the operator's side of the machine. The job is a "wrap around" operation, four 1½ by 1½ by 3/16 in angles are being formed simultaneously.

DESIGNING A SEAL

(Continued from page 27)

1. Vortices always exist in pairs. This result was to be expected since no momentum is supplied or removed axially.

2. Vortices develop gradually, not instantaneously. An actual instantaneous action is not to be expected in a natural phenomenon; but it was doubtful at first, whether the process of forming the vortices could be slowed down sufficiently to be studied.

3. Taylor's speed criterion was found to be correct even with the condition of finite length of the annulus. In every case for which computation was made, the predicted speed was a value intermediate between the speed at which the couette flow pattern was observed to break down and the speed at which the vortex systems were fully developed throughout the annulus.

4. Vortex ring cross sections were very nearly square as the top and bottom boundary planes of the individual vortex rings first became visible. This confirmed the work of Taylor who made his computations for the instant at which the instability was first manifested.

5. Data was obtained which made it possible to compute the number of vortex pairs that will form in any annulus of given dimensions. This makes it possible to design annuli in which a pre-determined number of vortices will form naturally.

6. At the first instant of visibility, the vortex cores were found to be symmetrically located and centered in each individual vortex. As the rotational speed was increased, the cores were observed to move so that they appeared to be in pairs, as shown in Figure 3.

7. It was observed that the size of the vortices is flexible within certain limits. When the length of the annulus is increased while the rotational speed is constant, the vortices become elongated to account for this increase in length although all vortices still are of equal size. The reverse is also true when the length of the annulus is decreased.

Applications

Vortex systems such as described will be formed in any case of fluid flow over a concave surface. An example is the flow over an airfoil with a concave trailing surface, such as is used with slotted wings. Another case is that of flow in curved channels which are deep compared to their width. Flow in curved pipes and conduits are further examples.

The fact that the Taylor vortex motion is entirely regular and is so very stable that a strong resistance is presented to the flow of fluid into, out of, or across the space occupied by the vortex rings can be utilized, under favorable conditions, to form a seal. The problem is the design of rotating shaft seals where it is desirable to prevent axial flow or leakage which is caused by a transverse pressure gradient.

Outline of Seal Design

The method of designing a hydraulic seal, based on the principles discussed, is to provide an annulus which permits the formation of a single pair of vortices of optimum size. Such designs are shown in Figures 4a, 4b and 4c.

The seal shown in Figure 4a is the simplest. It consists merely of a rectangular groove cut into a rotating shaft which is enclosed by a fixed, cylindrical housing. The direction of rotation of the vortex pair is shown in the figure.

The effectiveness of this seal is increased appreciably if it is arranged as in Figure 4b. Here the groove is cut deeper and a collar or ring of some kind is placed as shown. There is less liklihood of oil by-passing the vortex seal and its resistance to a pressure gradient is increased.

A useful variation in the design is that shown by Figure 4c. In this case the collar is fastened to the rotating shaft.

The research on this seal has not been completed and the pressure gradient which one pair of rings of a given size will withstand is not definitely known. It is certain that this pressure increment is limited so that for higher pressures it will be necessary to use several seals in series as is the case in labyrinth seals. For fairly high speed seals, (above 1000 rpm for SAE 10 motor oils), the ratio *"d/a"* should be from 2.70 to 2.80.

If the clearance *"a"* is too small according to this ratio, a slight, steady leakage will result. When *"a"* is too large, the leakage becomes heavier with greater values of *"a"*.

Advantages

The advantages of this seal may be summarized as follows:

1. A reduction of power consumption.

2. Simpler construction. It is not necessary to use rubber, leather, springs, bellows, carbon blocks, etc.

3. Less space is required. In each case for which seals have been designed, less space has been required than for the previous seal.

4. A great reduction in maintenance since there is no rubbing or wear of any of the parts.

The principal disadvantage is that the seal is not operative below the initial sealing speed. If there is a static pressure acting on the seal, it would be necessary that a mechanical seal which could be released, perhaps by centrifugal action, be used. In cases where the oil or other fluid flows back into a sump or reservoir under static conditions, this type of seal is effective.

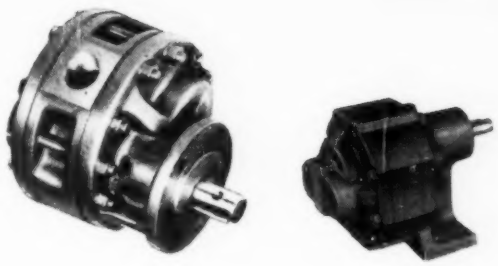
ADVANTAGES OF HYDRAULIC POWER

The transmission of power by hydraulic means offers definite advantages over mechanical transmission in many types of applications. Some of these advantages are:

1. **Elimination of complex mechanism, such as a multiplicity of gears, cams, levers, etc.**
2. **Smooth, flexible, quick action without vibration; action not affected by load variations.**
3. **Provides a cushioning effect on machinery and an automatic release of pressure at overload.**
4. **Extreme flexibility in the location of the hydraulic units and in the characteristics of the motions obtainable by the use of various combinations of units. This makes it possible to combine in one machine several operations to be performed in fully controlled sequence.**
5. **Infinitely variable rotary or straight line transmission of power control within limits in either direction.**
6. **Full control of timing and volume of desired pressure applications.**
7. **Rapid traverse, followed by slow power stroke and rapid return at end of stroke, with consequent saving in operating time and increase in production of many types of industrial machines.**
8. **Minimum manual control and labor.**
9. **Low power cost; low maintenance cost; economy in operation.**

—Adapted from Technical Bulletin Number B-4, Sun Oil Company.

HYDRECO Leads Where HYDRECO Pioneered
Complete Oil-Hydraulic Control Systems



HYDRECO PUMPS

HYDRECO Pumps are designed and built for long service under tough, everyday conditions. Because of their basic simplicity, HYDRECO Pumps withstand shock loads and pay dividends in long life, efficiency and low maintenance costs. Pumps are of spur gear type; offered in four basic series in capacities ranging from ½ GPM in the smallest to 150 GPM maximum in the largest. They can be operated at pressures up to 1000 P.S.I.

HYDRECO CYLINDERS

HYDRECO Hydraulic Cylinders are built to the same high standards typical of HYDRECO'S Pumps and Valves. Cylinders are manufactured with various strokes, diameters, and fastening or mounting equipment for wide application. HYDRECO Cylinders are manufactured as either single acting, double acting or telescopic types.

HYDRECO VALVES

For years, HYDRECO has pioneered in the development of a comprehensive, diversified line of control and auxiliary valves, designed and built according to specific job requirements. HYDRECO Valves are engineered for various pump volumes—for any installation where HYDRECO Cylinders or Pumps are used.

To simplify installation problems, HYDRECO units are available in various combinations such as: integrated pump, valve and tank units; assembled tank and valve units; pump and valve units; and other combinations for various applications.

HYDRECO engineers welcome the opportunity to discuss the application of oil-hydraulic control systems for your equipment. Our long experience in applied hydraulics is available without obligation. Call us on your next job.

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HYDRAULICS AND THE TANGENT BENDER

(Continued from page 29)

adjusting of the machine cut down production rates.

With the introduction of the improved double wing model by Struthers Wells after the recent war —the machine shown in Figures 2 and 3—a switch to hydraulic power was made.

Production Advantages

Several important production advantages were gained.

Of primary importance was a marked increase in the quality of the finished products. Since the hydraulic cylinder exerts a steady, continuous flow of power, the action of the rocker plate die irons out the metal under a constant tangential pressure. Full advantage is taken of the design of the die. Cylinder "jump" is entirely eliminated. Since with hydraulic power the rocker plate die and the radius die meet at the same location on every cycle under the same pressure, orange peel is practically forgotten. One major refrigerator manufacturer has used the hydraulic powered machine in uninterrupted production for more than six months without producing a single shell that had to be rejected.

Furthermore, the steady application of power throughout the die forming action takes advantage of the plasticity of metal and causes it to flow around the changes in contour. Since no stress is created the radius section of the metal is just as strong as the straight section areas.

Hardly less in importance was the decrease in power requirement from 25 hp to 10 hp. This power reduction involved a floor space saving of approximately 33 1/3 percent. Even with the power reduction, hydraulic operation made possible the building of machines of more rugged design, extending the range of work handled to heavier sheets and permitting much wider secondary die possibilities.

With the steadily gaining practice on the part of machine builders to incorporate as much of the operating elements as possible within the machine main housing, hydraulic operation is counted as a definite advantage. Elements necessarily outside the machine frame must be kept to a minimum in overhang of floor space and in size.

To illustrate the gain in power in the shift to hydraulic operation and at the same time keeping in mind the space factors let us look at the power of two cylinders. First, the 5¾ in clamping cylinder on the single wing tangent bender. At 1000 psi this cylinder exerts a clamping pressure of approximately 26,000 pounds. Through the leverage of the swinging arm assembly movement, the clamping pressure is multiplied to 52,000 pounds before the die action starts. To accomplish the same result with air at 100 psi would require a cylinder 18¼ in diameter. Next, the cylinders which operate the wings are 3½ in diameter and at 1000 psi they exert 9600 pounds wing thrust on each wing which has two cylinders. An air powered machine would require cylinders of 11 in diameter.

Variations in stock thickness is not a problem with hydraulic operations as dies of the automatic compensating type may be used to care for the commercial variation in the gauge of the material and production is continuous with sheets as supplied.

Hydraulic power is supplied from a compact, self-contained unit, designed and built exclusively for these machines by a leading manufacturer of hydraulic equipment. The unit is mounted within the machine housing. The diagram represents the functional elements of the hydraulic system for the single wing machine.

In the double wing machine the hydraulic circuit functions as follows: with work loaded in the dies, the main ram is brought forward at rapid traverse; the automatic two-volume circuit shifts from rapid traverse to slow or high-pressure traverse as the work is contacted; the wing cylinders are then brought forward, either individually or simultaneously and perform the bending operation or operations; the wing cylinders and the ram cylinder retract in turn; and a carriage cylinder turns the carriage 90 degrees, freeing the finished work for unloading. In the single wing design, as illustrated, the last movement of the ram retraction turns the swinging wing assembly through a 90 degree turn to accomplish the same purpose.

The change to hydraulic power in the Tangent Bender also involved several safety elements. The sound of escaping air in any pneumatic machine is often a source of uneasiness among plant workers. Momentary diversions increase the tension under which the operator works and tends to slow production or results in a laxness of normal precautions against mishaps which cause accidents and injuries. The quietness of hydraulic operation has done much to build the confidence of the operator. This is a production advantage as well as a safety factor—particularly in the case of inexperienced operators and nearby workers.

ACCUMULATOR APPLICATIONS

(Continued from page 23)

justable through hydraulic and limit switch regulators. Upset pressure is controlled through the accumulator. Platen traverse is controlled by means of a direct-acting type cam controlling the stroke of the piston pump. This eliminates variations in the speed of platen movement and the necessity of a "warm up" period before operation to insure consistent welds. Full automatic operation also eliminates all human errors and is particularly important when welding stock with critical metallurgical properties.

Second Use of Accumulator

This type of accumulator use, i.e., for the storage of the output of a relatively small hydraulic power source while the demand is low and then made available for phases of high demand may be contrasted to the accumulator use in a press type machine in which the accumulator supplies a force to oppose the weight of the platen.

The platen of the press type multi-spot welder, weighing several tons, is raised and lowered by means of a double acting piston and cylinder. The lower end of the cylinder forms a closed system with the accumulator. In this system, a hydraulic pressure sufficient to hold the platen in a raised position is maintained. Lowering of the platen is accomplished by the introduction of a relatively low total hydraulic pressure in the upper cylinder. This counteracts the pressure in the closed system and forces the fluid in the closed system to return to the accumulator, compressing the gas in the accumulator bladder. This, assisted by gravity, causes the platen to lower.

The piston rod diameter is made as large as practical to reduce the volumetric requirements of this latter phase. This design permits the use of a 30 gallons per minute instead of a 60 gallons per minute pump that would be required without the use of an accumulator and a large piston rod. This design resulted in a saving of over two thousand dollars in equipment for each machine.

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For tops in precision oil control valves, look to Double A Hydraulic Hi-Speed. Now combining Hydraulic-Hi-speeds' established engineering know-how with Double A's precision manufacturing facilities and their efficient management.

Every valve of our manufacture is fully guaranteed.

We carry many standard valves in stock for immediate delivery.

If your hydraulic valve problem is one of application, quality or delivery we can help! We are as near as your telephone. Just call our Sales Office in Detroit, Tyler 57711, or our Manufacturing Plant, Manchester 4511 or contact our nearest distributor listed below.

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Haskel Engineering & Supply Co., Glendale, Calif.
Tee Engineering Corporation, Logansport, Ind.
Alex M. Sneddon, Long Island, N. Y.
The Rucker Company, Oakland, Calif.
The Battersby Company, Philadelphia, Pa.
J. Boyd Coates, Philadelphia, Pa.
Pump Engineering Company, Seattle, Wash.
Robert J. Wylie, St. Paul, Minn.
George Worthington, St. Louis, Mo.
Dwight A. Johnston, Youngstown, Ohio

Applied HYDRAULICS DIGEST

Abstracts, summaries and listing of articles on hydraulic and associated applications in industry; reports on prepared papers, talks and discussions of special interest to the hydraulics field.

Remote Hydraulic Control

Harry P. Kupiec, *Product Engineering,* v 18, November 1947, pp 136-137.

A newly developed all-hydraulic control system, lighter and lower in cost than many mechanical and electrical systems, for use in lines of any capacity at pressures to 3000 psi and higher is described and shown by schematic diagrams. The system may be used in place of many well known systems for remote valve control. Multiple sets may be used for sequencing operations or as safety switches. Graphs indicate savings in weight and cost over a wide range of line capacities.

Fluid Film Clutch

Otto E. Wolff, *Machine Design,* v 19, December 1947, pp 135-137.

Several clutches of the fluid film or torque-limiting type of design are described and illustrated. In addition to such tool applications as power screw drivers and nut runners in which the free-slipping torque is sufficient to reengage the clutch as soon as it is removed from the work. Suggestions are made for such applications as safety overload clutches for electric motors, hydraulically loaded slip clutches in automatic transmissions, machine tool feed adjustments and in variable speed transmissions. For example, slip loss in the hydraulic torque converter, which may be tolerated during low speed acceleration, should be held to a minimum at normal operating speeds. By incorporating a centrifugally loaded slip clutch into the converter, shift to direct drive may be made by a momentary deceleration of the engine and shift back to converter drive is automatic whenever the transmitted torque becomes excessive or the speed drops too low.

Air Operated Devices Aid Paper Maker

Fred R. Erbach, *Compressed Air Magazine,* v 52, December 1947, pp 306-308.

An abstract of a paper presented before the American Pulp and Paper Mill Superintendents Association, Chicago, May 1947.

A discussion of a number of the pneumatic control and operational devices which the author believes are preferable on heavy duty paper making machinery. Devices given attention include air operated diaphragms for clutches and press roll loading; air cylinders for center-wind and board reels, lifting of transfer arms and as an automatic air guide; air motors as a power source for frequent or rapid reversal and for the movement of heavy loads at slow speeds. In most cases under discussion the air operated equipment supplanted manual operation.

Some Modern Aspects of Steel Plant Lubrication

C. E. Pritchard, *Lubrication Engineering,* v 3, December 1947, pp 64-68.

Based on a paper presented before the Buffalo-Rochester section, American Society of Lubricating Engineers.

A review of the salient facts of good lubrication practice as applied to the method for properly maintaining the lubricating equipment, rehabilitation and inspection of bearings and scheduling of the lubricant application. The establishment of a central repair station and its effective use is stressed in the building of a standardization program. Lubrication surveys and the development of a program for insuring systematic attention to every piece of equipment as needed are discussed and sound, practical suggestions offered.

Hydraulic Forming of Stainless Steel

William C. Brice, *Materials & Methods,* v 26, November 1947, pp 68-70.

An unusual and ingenious application of hydraulic pressure to complete the forming of an 18:8 stainless steel milker unit pail. Liquid pressure alone is used. The can after a third draw is slightly over 9 in dia. The hydraulic forming operation expands the diameter to approximately 12 in while decreasing the depth from about 17 to 15 in.

The workpiece after the third draw is washed, annealed and pickle cleaned, has a top flange formed and the excess metal is trimmed. It is then inverted over the male die, the lower half, and a leather gasket placed under the flange of the can to seal off the bottom. The female die is attached to the ram, which seals the neck of the can by serving as a holddown. When closed the female die holds the flange of the can against the leather gasket with a pressure of about 2300 psi.

Pressure for the operation is built up in a bulging cylinder. The liquid is admitted to the space around the male die and inside the workpiece through an inlet pipe in the die from the pressure cylinder under the press. A second pipe fitted with a spring valve opening from the top of the male die provides an air outlet. The liquid fills the space between the inside of the can and the lower die, exerting an outward and upward pressure that expands the stainless steel against the walls of the female die. An expansive force of about 300 tons is exerted for about 30 seconds. A liquid return valve is then opened, the liquid drained off from an intake at the bottom of the male die and returned to the bulging cylinder.

Sections of the female die open horizontally allowing finished pieces to be removed from the press. The

(Continued on page 37)

that the trouble had to be in one of four places.

the mechanical efficiency of the circuit.

PRESSURE TROUBLE · HYDRAULIC OILS AND HANDLING NOISE IN SYSTEM · REPORTING

By EARNEST V. SEBORG
Hydraulic Engineer
Barnes Drill Co.

THE APPROACH to any problem is extremely important. When trouble occurs in a hydraulic system, the approach to correcting this trouble can not be over emphasized.

The best approach to hydraulic trouble is to obtain the hydraulic circuit and study it sufficiently until you know the function and purpose of each pump, valve, motor or cylinder.

Next study the cycle of the machine to understand the sequence of operation in your hydraulic circuit. In doing this on some machines, it is necessary to know how operations are sequenced electrically by means of limit switches or pressure switches and solenoid valves. A few years ago all sequencing was done by means of pilot valve and pilot operated valves or pressure operated valves. Today a great many of these pilot valves and pilot operated valves have been replaced by limit switches and solenoid operated valves. This makes possible more rapid and more accurate operation. It also means that the hydraulic maintenance man should understand when and how the electrical circuit takes over either by means of push button, limit switch, or pressure switch.

Many of you are probably thinking that you have fixed many hydraulic troubles without the above approach, and you have. You also know of jobs where you worked long hours taking one valve apart and then another and another because you did not know enough about the circuit, the valves and the machine to isolate the trouble.

Pressure Trouble

In many instances, knowing the circuit does not tell you the exact valve or place in the circuit where your trouble is located, but it will at least show the parts of the circuit where it cannot be and consequently limit your survey to a number of valves and pipes.

An example of this was encountered just last week in our shop. A machine had been put into operation. It operated all right for several hours and then quit. A pressure gauge on the pressure side of the pump indicated less than 50 psi. The relief valve had been set for 350 psi. A knowledge of the circuit showed that the trouble had to be in one of four places.

The pump could have gone bad, the relief valve could have stuck, a solenoid-operated 4-way valve could have stuck in a partly closed position, or a pipe line could have sprung a leak. The most likely trouble seemed to be the leaky pipe but this was not the easiest to check, since some of these pipes were in the tank under oil. The solenoid valve was checked and found to be functioning OK. In other words, the solenoid was properly shifting the spool. The next easiest thing to check was the relief valve. If the relief valve discharge had been piped to tank by itself, a flow out of this line would have indicated that the relief valve plunger was stuck. Since this line was piped in with the discharge of another pump, it was necessary to take the cap off the relief valve and make sure the plunger was free, which it was. Checking the 4-way valve and the relief valve took about ten minutes time.

The trouble now had to be in the pump or in the piping. The best way to check the piping was to lower the oil level in the tank as far as possible and still keep the pump suction under oil. This was done and the pump operated. The leak was located in a pressure pipe which had not been properly pulled up. This leak was particularly hard to locate because it was near a discharge line and the oil appeared to be coming from the discharge line. A knowledge of the circuit showed, however, that oil could not come from this discharge line at this time.

Hydraulic Oils and Handling

Probably the greatest single factor in hydraulic system trouble is the hydraulic fluid. In most machine hydraulic systems, this is a good grade turbine oil. From the maintenance man's point of view, the oil recommended by the machine manufacturer should be used. If a common oil is to be used in several machines, the approval of the machine manufacturer should be obtained before making substitution. He may have a very definite reason for using a certain oil.

Besides using a good hydraulic oil (a lubricating oil should not be used) it is necessary to use an oil of the right viscosity where maximum overall efficiency will be attained. A lower viscosity oil than the ideal will cause leakage and reduce the volumetric efficiency of the pumping unit. This in turn will reduce the mechanical efficiency of the circuit.

Too high a viscosity oil than the ideal will put an additional load on the pump and thus also reduce the mechanical efficiency. These things have been taken into consideration by the machine manufacturer when he recommends a certain oil for a certain system.

The handling of hydraulic oils to keep them clean is very important. This can best be shown by an illustration again from our own shop. A test stand for running-in hydraulic cylinders was operated by a 20 gpm variable delivery piston pump which sucked oil through a strainer with .005 in openings. This pump had to be regularly serviced every three months and the valve plate refitted as well as other worn parts replaced. A survey showed that small particles of abrasive accumulatd in the oil and circulated through the strainer and pump. This abrasive was coming from the honing operation on the cylinders even though the cylinders were washed in gasoline and blown out with air after honing. A filter was put into this system and the time between repairs was lengthened to two years.

For machines not on running-in operations, where the oil does not come in contact with new parts and clean them, it may not be necessary to have a filter in the circuit, but a regular system of cleaning the oil will pay dividends in cutting down servicing and money spent for oil. Piston rods, pump and valve parts, rod packings, and seals of all kinds are cut to pieces by dirty oil. This of course causes leaks and loss of oil as well as machine down time to replace parts.

A system which works very well was set up in a plant a few years ago. A filtering unit consisting of tank and filter with circulating pump was installed in one corner of the shop. Two tanks were made on wheels so that they could be wheeled to any part of the shop. Each of these tanks was of sufficient capacity to hold all of the oil from the largest capacity machine. Each of the tanks also had a motor driven pump attached. One tank was marked "For Dirty Hydraulic Oil" and the pump was arranged with check valve so that oil could only be pumped from sump of machines into this tank. The other tank was marked "For Clean Hydraulic Oil" and pump arranged so that oil could only be pumped from this tank into machines. Oil is sucked from machine into "Dirty Hydraulic Oil" tank and transported to the filter. The "Clean Hydraulic Oil" tank which has previously been filled with filtered oil is then taken and pumped into machine. The "Dirty Hydraulic Oil" tank is pumped out into filter tank and is ready for use. The "Clean Hydraulic Oil" tank is returned to filter and again filled with filtered oil. This system is taken care of by one man.

All the machines in the shop have periodic changes of hydraulic oil. A check on the oil after two years use showed that it was still like new oil. A marked decrease in leaks and down time has been noticed, and the replacement oil bill is greatly decreased.

Noise in System

When a hydraulic system that has been functioning quietly becomes noisy, it is very often caused by pump cavitation. In other words, the intake line to the pump is limiting the flow into the pump to such an extent that the pump creates a vacuum on the suction side. Cavitation noise is usually continuous when the pump is running. When a strainer is used on the suction line, cleaning this strainer will eliminate cavitation noise. If no strainer is used, take the intake pipe entirely off of the pump and make sure that a piece of waste or some other foreign material is not blocking this line. If the foreign material is not found in the line, it may be necessary to take the pump itself apart to be sure the suction is open.

Noise in a pump may also be caused by mechanical failure. This can usually be distinguished from cavitation because it usually is a clicking sound of the same frequency as the pump rpm. Cavitation, if it continues, may cause pump failure.

Relief valve or sequence valve noises may be distinguished from pump noises because they are heard only when the pressure in the system has reached the pressure of the relief or sequence valve. These can be classed as two kinds. One is the surge noise that is heard when the valve opens. The other is the noise caused by the continuous flow of oil through the valve. Surge noises in relief valves can sometimes be eliminated by turning the discharge pipe away from the bottom or side of a tank. Surge noises are sometimes encountered in sequence valves if the valve does not open fast enough to eliminate a surge pressure beyond the setting of the valve. The proper design of the valve and its application in a circuit will usually eliminate surge pressure noise.

Noise caused by the continuous flow of oil through a relief valve is usually caused by a vibration setup in the relief valve spring, causing the valve to squeal or howl. Sometimes changing the spring in the valve will eliminate this noise. Other times it might require a new valve with different seat, or different plunger design, depending on the amount of oil and pressure at which the relief valve operates. When asking for a replacement valve, it is well to specify the pressure at which noise occurs.

Reporting

When reporting trouble to a machine manufacturer, give him as much information as you can. Be sure to give him the serial number of the machine.

DIGEST

(Continued from page 34)

uniform application and holding of pressure results in pails with no appreciable spring-back. Tolerances were held without difficulty. About 50 pieces per hour were formed.

The drawing operations are made on the same press as the final hydraulic forming operation by the use of different sets of mating dies for each step.

Specifying Hydraulic Fluids

E. A. Reehl, *Product Engineering,* v 18, October 1947, pp 122-125.

A brief, practical survey of seven primary characteristics to consider in the selection of hydraulic fluids with comment on possible future trends in the hydraulic liquid field.

Frequency Response Measurements of Hydraulic Power Unit

M. R. Hannah, Paper as prepared for ASME national meeting December 1-5, 1947.

A report on the dynamic response of typical aircraft hydraulic power units to include transmission and associated stroke control. Suggestions are made for improving response of the unit.

Hydraulic Control for Trailing Implements

E. W. Tanquary, *Agricultural Engineering,* v 28, March 1947, pp 91-94.

A summary of the situation regarding the standardization of hydraulic cylinders for trailing implements. Rather full use is made of a paper, "Trend in Power Control for Farm Machines" by W. A. Harper, which discusses such a proposed standardization sponsored by the Advisory Engineering Committee of the Farm Equipment Institute.

What To Look For in Hydraulic Oils

Anthony J. Zino, Jr., *American Machinist,* v 91, November 6, 1947, pp 93 and ff.

This series is announced as seven articles.

Part I summarizes six service properties (viscosity, viscosity index, demulsibility, oxidation stability, lubricating value and rust and corrosion preventive qualities) and gives, by illustration, typical failures when the hydraulic fluid lacks one or more of these essentials.

Ibid., November 20, 1947, pp 112-116.

Part II, "Viscosity." Definition and derivation of absolute and kinematic viscosity are given. Explanation of testing techniques and devices and a viscosity conversion chart and recommendation for hydraulic oils by manufacturers of four types of pumps are covered.

Ibid., December 4, 1947, pp 112-114.

Part III, "Viscosity Index." VI, the measure of resistance to viscosity change, is discussed; formula and tables are given and explained; the effects of low VI fluids are listed. The viscosity-temperature relationship is illustrated by means of the ASTM chart the use of which is explained.

(Continued on page 42)

RACINE
Announces

New! VARIABLE VOLUME OIL HYDRAULIC VANE TYPE PUMP

ANOTHER RACINE HYDRAULIC ACHIEVEMENT — the new Model J Variable Volume Oil Hydraulic Pump. Compact Vane Type design allows installation of this pump in a space as small as 6" x 6". It will deliver 1000 pounds pressure per square inch and will maintain a 90% volumetric efficiency.

Variable Volume feature allows horsepower requirement of system to be held to demands of the maximum load. Racine Hydraulic engineers welcome the opportunity to review your needs and make recommendations for complete hydraulic circuits. Write for Catalog P-10-C. Address RACINE TOOL AND MACHINE CO., 1774 STATE ST., RACINE, WISCONSIN.

OUTSTANDING FEATURES

ADJUSTABLE VOLUME — Pump can be set to deliver exactly the proper volume of oil for any given job.

ACCURATELY BUILT—All parts precision made. Accurately ground vanes of special steel are self-compensating for wear. Rotor shaft mounted in anti-friction bearings. Entire pump is self lubricated.

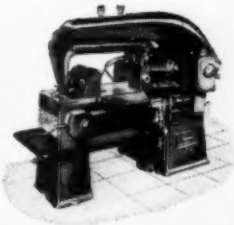
LOW COST—Quantity production and standardization of parts make possible low cost that compares favorably with constant volume non-adjustable pumps.

OTHER RACINE HYDRAULIC PUMPS

Variable Volume Pumps with either manual, mechanical, hydraulic or electrical volume control are available in capacities to 30 g.p.m. at pressures of 50 to 1000 lbs. p.s.i. Four-Way, Balanced-Piston Sleeve-Type hydraulic valves are also available in a wide range of styles and portings. Sizes ⅜" to 1½" I.P.S., lever, foot, pilot or solenoid operated.

RACINE *Hydraulic* METAL CUTTING MACHINES

If you have a metal cutting job whether it be soft aluminum or hard tool steel, tubing or bar, Racine has a saw in its complete line that will do the job. Sizes range from 6" x 6" to 20" x 20". Ask for catalog No. 12.



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STANDARD FOR QUALITY AND PRECISION

NEW PRODUCTS

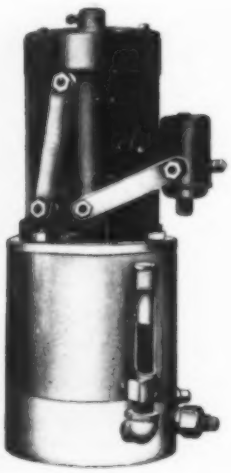
For additional information on any of these products, mark the end key numbers on the card bound in this issue and mail the card.

New Pump Series

Adel Precision Products Corp. announces a new series of gear type hydraulic pumps designed for 1000 psi service. Rated capacities from 1½ to 60 gpm at 1800 rpm are obtainable. Use the Business Reply Card, mark NP-1.

Fluid Power Unit

The Jerome Hydraulics Co. have just announced a new type fluid power unit, the Jerome Model 1100 Pack O'Power. The unit includes a pump, a six or twelve volt motor, reservoir and oil filter relief, check, return flow regulator and electrically operated by-pass valves. Interchangeable pump capacities up to 4 gpm and pressures to 2000 psi are available. The reservoir has an additional connection for an auxiliary tank.



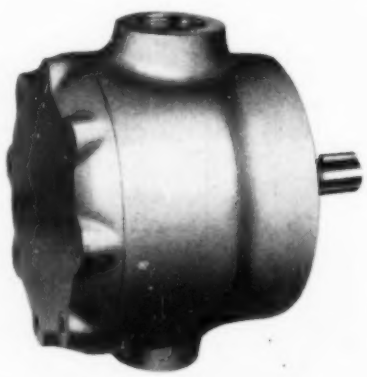
The unit may be mounted vertically or horizontally and is 5¾ in dia and 14 in high. Other adaptations of this model include 110 v, belt driven and double acting cylinder actuation. Use the Business Reply Card, mark NP-2.

Flow Control Valve

Pneu-Trol Devices, Inc., have recently announced a flow control valve to control cylinder speed and still allow unrestricted flow from the cylinder. The new flow control valve is only slightly larger than the pipe size, permitting compact piping arrangements. It is available in ¼, ⅜ and ½ in pipe sizes. Use the Business Reply Card, mark NP-3.

Constant Displacement Pump

A new constant displacement, hydraulically balanced pump has been added to the hydraulic equipment line of the Sundstrand Machine Tool Co. This pump has been designed and tested for continuous duty at 1000 psi and for intermittent service up to 1500 psi.



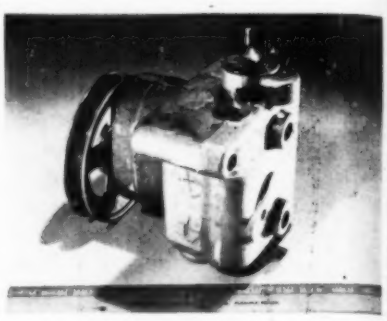
Three basic sizes covering the complete range of 2 to 75 gpm capacities will be available. Interchangeable cartridges provide four capacities within each of the three basic sizes. At present, 10, 13½, 20½, or 27½ gpm capacities (at 1000 psi) can be furnished.

A mechanical oil seal prevents oil leakage along the shaft, multi-porting connecting all pumping areas assure unrestricted flow and the large displacement within the relatively small housing are additional features of the new design. Use the Business Reply Card, mark NP-4.

Midget Hydraulic Power Unit

A hydraulic power unit, the "Ten-Ton-Tony," only 6x7x9 in size and capable of supplying three gallons of oil per minute at 1000 psi at 1200 rpm or 4½ gpm at 1000 psi and 1800 rpm is announced by Hydro-Power, Inc.

The gear pump is mounted integrally with the operating valve, which has a ball-handle lever operated at forward, neutral or reverse positions. Check and relief valves are built in the main valve body. It



is equipped with a pulley for belt drive. Use the Business Reply Card, mark NP-5.

Lubricating Injectors

Centralized lubrication injector systems, automatically controlled and manually timed, are offered by Lincoln Engineering Company. The injectors are designed for single or manifold mounting, for installation on one or more machines. The systems may be equipped with manual, automatic or portable guns. Use the Business Reply Card, mark NP-6.

Sump Type Filter

Five models of sump type liquid filters ranging in capacities from 5 to 30 gpm are being offered by Marvel Engineering Co. The filter has no moving parts, featuring a "Synclinal" design filtering unit.

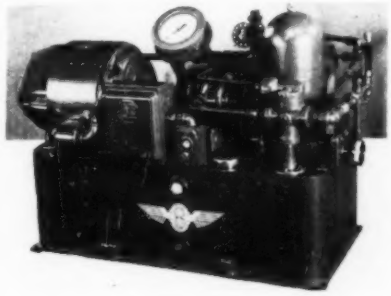
The special construction requires less pressure and permits a lower rate of flow.

A guard enclosing the filtering insert, illustrated, reduces the danger of injury or collapsing of the unit by careless handling. A bulletin is available. Use the Business Reply Card, mark NP-7.

Power Pack

A new self-contained hydraulic power pack, Model PP-113 is now in production by Greer Hydraulics, Inc. Especially designed for the textile industry, this unit supplies the required hydraulic power for rolling mills and automatically maintains uniform pressure on the calender rolls regardless of the varying thickness and seams in the material.

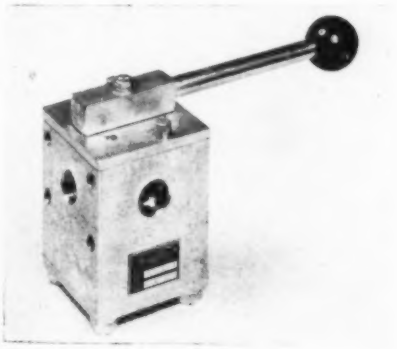
The unit is equipped with a reservoir, motor and pump, an overload cutout magnetic starter, relief and relay valves, accumulator, pressure



gauge, manifolds and control valves. Use the Business Reply Card, mark NP-8.

Shear-Seal Valve

Saval Company announces the Shear-Seal valve for handling oil or water up to 10,000 psi; or air or gas to 3000 psi. Sizes are available to 1½ IPS; solenoid and pressure actuated valves are available in

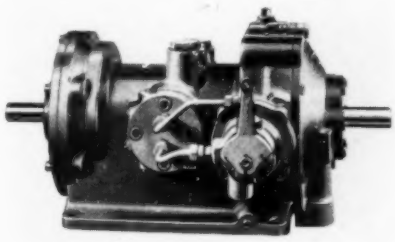


smaller sizes. The unit illustrated is for pressures to 5000 psi with ½ in pipe size and requires a force of twelve pounds with a 6 in handle. Use the Business Reply Card, mark NP-9.

Variable Speed Transmission

A new two-way variable speed transmission available with four styles of controls is announced by The Oilgear Company.

The variable speed transmission consists of a volumetric, variable delivery, radial rolling piston pump driving a constant displacement radial rolling piston motor. Integral relief valves installed in fluid passages protect against overload. Flange mounted controls are interchangeable.



Model AHB-33, illustrated, shows the two-way transmission with hydraulic servo-motor lever control.

Input speed of 1750 rpm will produce output speeds variable from 0 to 1600 rpm in either direction with a normal torque of 90 in-lb.

Hand screw, hydraulic servomotor lever, hydraulic two-speed and electric three-position remote control devices cover the requirements of a wide variety of applications.

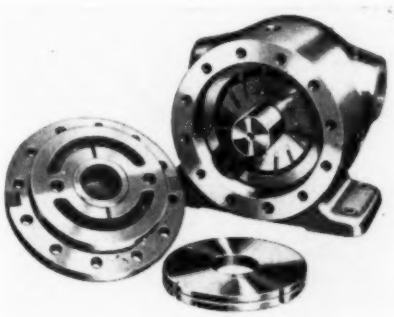
The new variable speed transmission is fully described with specifications in Bulletin 67110. Use the Business Reply Card, mark NP-10.

Hydraulic Stock Feed

The Haller Machine & Manufacturing Co., Inc., announces their Model D-600 Hydraulic Stock Feed. The gripper, feed mechanism and stock retainer are hydraulically controlled. The feed handles stock up to 4 in wide and 3/32 in thick. Designed for direct drive from the press ram, length of feed is adjustable from 0 to 5 inches. Use the Business Reply Card, mark NP-11.

Adjustable Volume Vane Pump

A manually adjustable volume vane type pump is announced by the Racine Tool and Machine Co.



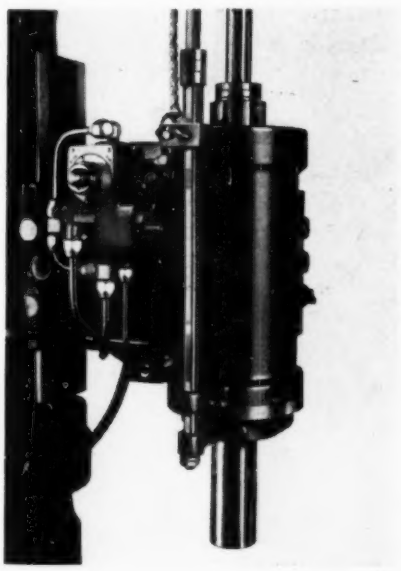
Designated Model J, the pump capacity is adjustable from 0 to 15 gpm at maximum continuous operation pressure of 1000 psi, and is available with foot or flange mounting. The pump is very compact, fitting into a space approximately 6 by 6 in. Use the Business Reply Card, mark NP-12.

Compact Power Unit

Designed to actuate hydraulic cylinders on farm, road building and industrial equipment, the unit is now being manufactured by Phillips-Drucker. The compact unit has a rated output of 15 gpm at 1100 rpm and a maximum operating pressure of 1200 psi. Use the Business Reply Card, mark NP-13.

Hydraulic Power Feed

The announcement of a newly developed hydraulic power feed for sliding head drill presses was recently made by the Canedy-Otto Mfg. Co. High efficiency with extreme



simplicity are embodied in this design. The hydraulic power feed will be available for attachment to existing models as well as standard equipment for new Canedy-Otto drill presses.

The unit may be operated automatically, semi-automatically, or manually and is provided with a convenient adjustment for various feed rates. Operating the unit in the automatic position produces a reciprocating action of the spindle. Use the Business Reply Card, mark NP-14.

Venturi Oil Filter

A proportional type oil filter for hydraulic circuits that operates efficiently in either direction is announced by Vickers, Inc. The venturi design limits maximum pressure built up across the cartridge and

eliminates the necessity of a by-pass valve. This action when installed in any horizontal system pressure line, the only maintenance required is the periodic replacement of the cartridge. Use the Business Reply Card, mark NP-15.

Hannifin Hydraulic Power Unit

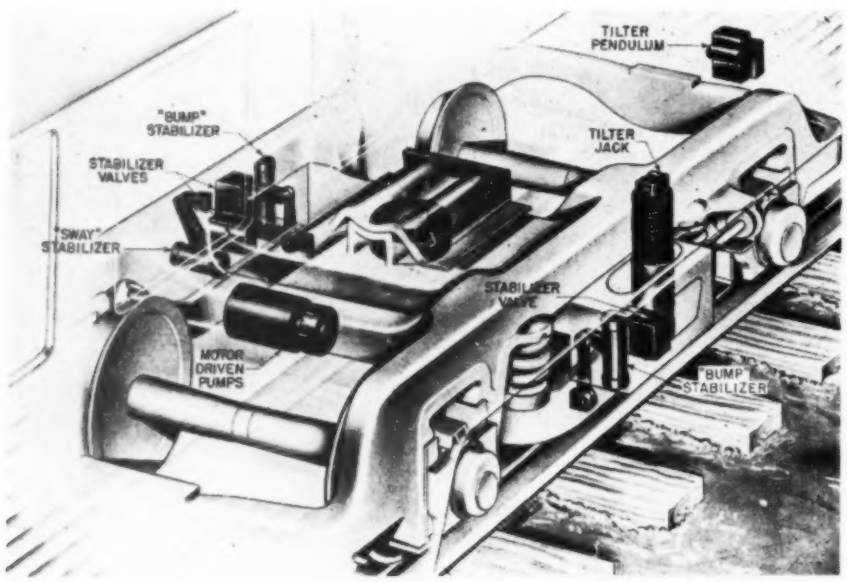
A power unit for use with hydraulic cylinders or hydraulically operated equipment, providing for any required pump capacity from one gpm up and for pressures to 2000 psi or more is in production by Hannifin Corporation. The standard unit includes pump, pressure relief and adjusting valve, flexible coupling and pressure gauge. Standard motors are used.

Hannifin Bulletin No. 110 contains engineering data on hydraulic

power applications. Use Business Reply Card, mark NP-16.

Stabilizer Increases Railway Comfort and Safety

A new high in riding ease and comfort for train and bus travelers is promised with the development of an "educated shock absorber" or stabilizer in which compensating movements for bump and sway are hydraulically actuated. Centrifugal effect is corrected for by a mechanical tilter jack operated by a gyro-controlled pendulum.



The invention of Dr. Clinton R. Hanna, Stanley J. Mikina, and Lawrence B. Lynn, of the Westinghouse Research Laboratories, the stabilizer is now being road-tested by one of the nation's leading railways. Significant contributions to the development were made by railway engineers. In addition, application tests with the stabilizer on highway equipment are planned by a large bus manufacturer.

The device for railway installation consists of six hydraulic cylinders and a pair of motor driven screw-jacks. Four "bump" stabilizer cylinders, two on each truck, compensate for vertical movement and two "sway" stabilizer cylinders, one on each truck, correct for lateral movement. Motor driven pumps maintain the flow of oil for the hydraulic system.

As the trucks come to a bump or dip in the track, a floating weight senses this motion, electrically operating valves to move the bump cylinders the exact distance in the direction required for compensation.

A similar action by the sway stabilizer cylinder moves the truck wheels laterally correcting for sidesway. Both of these compensating actions are completed in three one-thousandths of a second. The application of hydraulic power of the stabilizer to the wheels, helping them move up and down, greatly increases the traction power. The motor driven tilter jack tilts the car body to the proper bank angle as it enters a curve.

High Pressure Pumps

The development of gear type hydraulic pumps Models 9000 and 9075 is announced by Aro Equipment Corp. Designed for continuous pressures of 1000 psi and 1500 psi intermittent service, Model 9000 will displace 8 gpm at 1800 rpm; Model 9075 displaces 15 gpm at 1200 rpm.

A pilot-type flush mounting face makes possible direct attachment or mounting by bracket. Pumps may be direct, belt, gear or chain driven. Use the Business Reply Card, mark NP-17.

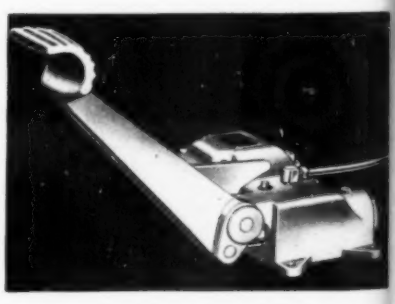
High Speed Solenoid Valve

A non-corrosive, full capacity, 3-way direct operating solenoid valve, Model DS-3, has just been announced by Airmatic Valve, Inc.

The newly-designed valve, to control single acting cylinders, eliminates pilots, levers and all other types of "indirect control." It can be mounted in any position and can be operated continuously. The valve is furnished in four standard pipe sizes ¼, ⅜, ½ and ¾ in. Use the Business Reply Card, mark NP-18.

Lightweight Hydraulic Foot Pump

Lyon-Raymond Corporation have added a foot pump to their list of hydraulic accessories. The pump is designed with a pedal return spring within the pump body; the pressure release is controlled by raising the pump pedal. This eliminates the necessity for a release lever and avoids the possibility of accidental release.



The unit has a sealed reservoir allowing the pump to be mounted in an offset position. With an oil capacity of 15 cu in, working pressures up to 1500 psi can be obtained with this pump. Special features of the pump are its light weight, adjustable relief valve, oil strainer and chrome plated piston. Use the Business Reply Card, mark NP-19.

COMPLETELY *Automatic*
PRESSING • FEEDING • EJECTING
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AND INDEX TABLE ACCESSORY

- Press ram and table dial operate in positive sequence. Both are operated HydrOILically through the control system of the MULTIPRESS.
- Single lever controls action of both ram and table for either single or automatic cycling.
- Tooling may be located at six stations around the dial.
- Cam within table housing provides automatic ejection of the finished parts (optional).
- Ram speed, tonnage, and rate of travel, as well as movement of the table dial, are easily regulated by the operator.

• Here's your answer to increased production—lower manufacturing costs—improvement of plant working conditions. The MULTIPRESS with the HydrOILic Index Table gives you *completely automatic* operation for countless applications, yet permits the use of unskilled workers on jobs usually requiring experienced operators.

There's a complete file of case histories, proving the outstanding results all industries have experienced after using MULTIPRESS. Write for the complete story, today, and also ask for Bulletin M-9.

The HydrOILic Index Table is also available as a separate unit for use on any hydraulically powered machinery. Write for details.

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DENISON
EQUIPMENT for APPLIED
HydrOILics

DIGEST

(Continued from page 37)

Ibid., December 18, 1947, pp 94-95.

Part IV, "Demulsibility." The effects of entrained and free water and of the "absorbed" water on life expectancy of the fluid and service performance are enumerated and the loss of lubricating value, destruction of sealant properties and increased chemical activity are discussed briefly. The du Nouy tensiometer for recording interfacial tensions of refined petroleum oils against water is described in some detail; an associated chart shows the relation of interfacial tension to acid content and sludge.

Several preventive maintenance suggestions are offered.

(to be concluded)

How Farm Implement Linkage Best Uses Control Power

Knud B. Sorensen and **Stanley Madill,** *SAE Journal,* v 56, January 1948, pp 32-34.

This excerpt from a paper* is a study of three linkage designs to illustrate the linkage most nearly producing the ideal rectangular work diagram for the lift cycle of a hydraulic cylinder. The authors give an initial design and two modifications. The initial linkage design gave high pressure peaks at the beginning or end of the cycle, most common at the end of the cycle in converting from wheel lift to power control. In the second linkage the angle between the two bellcrank arms was widened, correcting the shortcoming. A larger bellcrank arm angle changed the cylinder's relative work stroke position, increasing the arm length as the cylinder extends and giving a uniform rate of mechanical advantage increase. The third linkage made constant cylinder pressure possible by reversing the bellcrank, so that it rotates in the opposite direction. This design reduced change in effective length of the bellcrank-to-axle link. The position of the bellcrank arms with respect to the cylinder stroke and wheel axle is a desirable mechanical advantage. The authors point out that the advantages of the two modifications may be effectively combined; they give a linkage correction for conditions under which the total work exceeds the system's capacity. An adjustable linkage control design is suggested which allows small tractors of low capacity power control to handle larger implements to maximum depth within their drawbar capacity. Another advantage is that a linkage using only part of the cylinder stroke gives quick lift.

*"Capacity Requirements for Power-Controlled Agricultural Implements", presented at SAE National Tractor Meeting, Milwaukee, September 17, 1947.

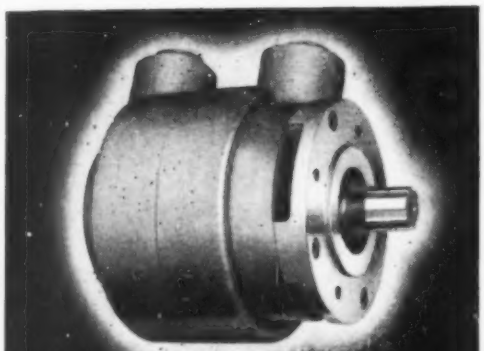
New Approach to Design

Anonymous, *Machine Design,* v 19, June 1947, pp 146-147.

Described as the invention of H. Ziebolz, this article describes a fundamental system for the development of any type of power transfer mechanism. All basic elements are cataloged and all known devices used for converting energy or power from one form to another are indexed with data arranged on catalog file cards, each carrying data and diagram for basic translator or power factor.

Built To Be The Greatest Value In The Field!

The New DUDCO Vane-Type SMALL PUMP Now Costs Only $150 *(Pressures Up to 3000 psi*



Here's an outstanding small series hydraulic oil pump ideal for applications requiring an economically priced high pressure pump, where competition hasn't allowed the use of higher priced 2000 psi pumps. Volumetric efficiency 97%. Overall length 8". Diameter 6½". Weight 60 lbs. Delivers 2 to 18 gpm at 1200 OR 1800 rpm. A revolutionary Dudco patented feature balances the radial vanes hydraulically for both pressure and flow, and eliminates bearing loads. These pumps are available in *completely packaged power units,* including relief valves, motor coupling, electric motor, filter, pressure gauge, outlet and return lines. Delivery within 3 to 4 weeks.

DUDCO SMALL SERIES PUMP
(2000 PSI)

Model No.	Del. GPM @ 1800 RPM*	Maximum Pressure PSI	Peak Pressure PSI	HP Input @ Max. Pressure
P-2	2	2750	3000	3.8
P-3.5	3.5	2750	3000	6.6
P-5	5	2500	2750	8.6
P-8	8	2250	2500	12.4
P-15	15	2000	2250	20.6
P-18	18	1750	2000	21.6

*Pump for volume shown also available for 1200 RPM operation

Also Larger Series DUDCO VANE-TYPE PUMPS

The P-32 series for 2000 psi up to 32 gpm, and P-60 for 750 to 1500 psi up to 80 gpm. Dudco small or large pumps can be used in combination for high volume low pressure and low volume high pressure requirements. (Also two series DUDCO MOTORS available.

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Formerly DETROIT UNIVERSAL DUPLICATOR CO.
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Write for Details

Ask for our descriptive folder and data sheets. Also we welcome inquiries about specific problems. Our engineering dept. will gladly advise you.

Sales Representatives In All Territories

Useful Literature

The publications listed are available without charge to our readers. For your convenience, mark the initial key number on the card bound in this issue and mail.

1. Tube Fitters' Manual... An authoritative 76-page handbook on the selection, sizing, layout and installation of metal tubing circuits has been published by The Parker Appliance Company. Handbook No. 111, the Tube Fitters' Manual, should be of particular interest to design, assembly and production engineers and to departments with hydraulic systems.

2. Oil Cylinders... Bulletin 700 published by Air and Hydraulic Division, Lindberg Engineering Co., presents full specifications of ten standard bore sizes, 2 to 8 in, and seven selective mounting styles for cushioned and non-cushioned hydraulic cylinders.

3. Flow Control Valves... A 4-page illustrated bulletin 45-35, describing the "Microfeed" Flow Control Valves made by Vickers, Incorporated, is available for distribution. Circuits of meter-in, meter-out and bleed-off control are shown. Designed for central system pressures up to 2000 psi, the control valves are of gasket mounting design, easily interchangeable and, with integral check valve, provide reverse free flow.

4. Vane Pump... A folder containing descriptive information and data sheets on the new 2000 psi Dudco balanced dual vanes rotary type pump is now ready for distribution by Dudco Products Company.

5. Seamless Tubes... A 68-page catalog on the line of seamless steel tubes made by the Steel and Tube Division of The Timken Roller Bearing Company is being distributed by that Division. One of the two sections of the catalog illustrates the manufacturing facilities.

6. Cylinder Circular... A circular on the new Electrol "500-1" series of hydraulic cylinders is announced by the manufacturer Electrol Incorporated. The series includes 8 models from ¾ to 3 in bore for maximum operating pressures to 1500 psi.

7. Oil Circular... A circular is available from the Gulf Oil Corporation on the two standard hydraulic oils supplied by this company, one of which contains a permanent, anticorrosion additive.

8. Hose Assemblies... The industrial catalog available from Resistoflex Corporation lists their low pressure hydraulic hose (to 500 psi) in sizes 3/16 to 1 in and their medium pressure hydraulic hose (to 2500 psi) in sizes from 3/16 to ⅝ in, as well as hose for other applications, end fittings and custom service of molded shapes.

9. Valve Bulletin... C. B. Hunt & Son, Inc., has included their line of air and hydraulic valves in Bulletin 107A. Data on sliding sleeve air valves in sizes to 1½ in and on lever and pilot operated hydraulic valves in sizes up to 2 in is contained in the bulletin.

10. Oil Purifiers... Honan-Crane Corporation, subsidiary of Houdaille-Hershey Corporation, has issued a 4-page illustrated folder describing their standard unit and central station oil purifiers.

11. Hydraulic Cylinders... The complete line of hydraulic cylinders of The Tomkins-Johnson Co. is shown in their catalog H-47 which is available on request. Low pressure, high pressure, adjustable and non-adjustable cushion action and double end rod types are illustrated with complete specifications.

12. Hose Assemblies... The C. A. Norgren Co. will send their Bulletin 450 on high pressure or their Bulletin 550 on low pressure hose assemblies for pneumatic systems. High pressure sizes run from ¼ to 1 in ID and low pressure sizes from 3/16 to 1½ in ID.

13. Hydraulic Unit... Catalog describing the Rapidraulic Junior, a hydraulic unit designed for clamping and similar applications, is issued by John S. Barnes Corp. Complete installation data, specifications and operating instructions are included.

14. Control Valves... Catalog 3C issued by Saval Company contains specification drawings of manually and electrically controlled valves, standard and heavy duty selector valves, shut-off valves and miscellaneous units made by this company.

15. Pump Catalog... A 28-page general catalog describing their full line of pumps is available from Brown & Sharpe Mfg. Co. Included are the 500 series rotary gear pumps designed for direct drive, high speed operation and for pressures up to 500 psi.

16. Fitting Catalog... An 8-page bulletin, Catalog No. 101, is offered by Flodar Corporation. The high pressure tube fittings described are furnished in straight, union, elbow, side and tube T and cross, with sizes ¼ to 1½ in.

17. Hydraulic Couplings... Bulletin No. 144, issued by Twin Disc Clutch Company, gives specifications and operating characteristics of five models of hydraulic couplings rated from ¾ to 20 hp at 1800 rpm. Installation data and mounting arrangements are included.

18. Cylinder Catalog... Miller Motor Company announces their new high pressure hydraulic cylinder catalog listing their unusually complete line of single and double acting cylinders, single rod and double rod end cylinders and others. Complete mounting dimensions are given on sizes from 1½ to 8 in bores.

19. Oil Filters... Purolator Products, Inc., will send their general industrial and machine tool catalog on their line of permanent and replaceable element oil filters on request. Specifications and useful engineering data are included.

20. Piston Pump... Bulletin 1-P, issued by Blackhawk Manufacturing Co. gives specifications and performance data on their P-104 general purpose twin piston-type, high pressure pump. Operating pressures run from 100 psi to 4000 psi from power sources up to 5 hp.

(Continued on page 46)

HYDRAULIC OILS

(Continued from page 21)

gear pumps, pistons in positive displacement pumps and on valves.

Film strength is that property which prevents metal-to-metal contact; lubricity is directly related to the chemical makeup of the oil. These properties together, both chemical in nature, determine the lubricating value of an oil. A third factor that must be considered is the degree of finish of the rubbing surfaces. Honed, lapped or superfinished surfaces reduce the friction and the rate of wear. Oiliness agents and extreme pressure additives, to build strong, adsorbed film, are often beneficial in establishing or maintaining a satisfactory lubricating value of an oil.

Gum solvency, the ability of an oil to hold gums and sludges in solution, is another factor for which no specification can be written. An oil processed with active solvents tends to hold incipient formations which may be harmful in solution, preventing their deposition on filter or pipe surfaces, in reservoirs or on control valves.

Corrosion and Rust Prevention

Corrosion in an hydraulic system is caused by acid attack on the bearings and other finished metal surfaces. Rusting is always the result of water contamination. Systems that operate intermittently, especially those with relatively long idle periods, are particularly susceptible to rusting because the moisture in the system then has an opportunity to condense. Water soluble coolants used on machine tools are active in rust formation. A leak of such a coolant into an hydraulic reservoir may result in seizing of valves.

Neutralization Number

The neutralization number or acid number is an index of the degree of acidity of an oil. It is useful both as an original specification of an oil and as a maintenance check to determine when an oil should be drained. One large user, for example, does not continue oil in service after an acid number of .50 has been reached.

After refining, hydraulic oils usually contain very small amounts of organic acids which, in an unused oil without additives ordinarily runs from neutral to 0.1. An untreated oil with a neutralization number higher than 0.1 will often exhibit a tendency to deterioriate more rapidly in use under sever operating conditions than an oil with a lower number.

Additives may tend to raise the neutralization number, so that the test itself is not conclusive. Except for viscosity, none of the usual specification data should be used independently as a determining factor in the selection of a hydraulic oil, in running down an operation trouble or in establishing an oil replacement policy.

Miscellaneous Physical Properties

There are a number of physical properties of hydraulic oils that are not always considered in specifications depending on operating conditions.

These are:

(1) **Pour Point,** the temperature below which an oil will not flow freely. This property is important only when oils are used in low temperature equipment or where the equipment is exposed to very low ambient temperatures. In such cases, the oil should be able to pass a cold test at least 25 F below the lowest expected operating temperature. Several hydraulic pump manufacturers recommend in their oil specifications that the viscosity of an oil should never exceed 4,000 seconds (Saybolt) at the lowest starting temperature.

(2) **Carbon Residue.** The carbon residue test is a measure of the percentage of carbon that remains in a sample after the volatile content has been driven off by heat. For all practical purposes, the test (Conradson) is obsolescent as a specification for hydraulic oils.

(3) **Color** of hydraulic oil is not a criterion of its quality. The color of any hydraulic oil darkens with use; additives may also tend to give an oil a darker color. Color is unreliable as a test.

(4) **Flash and Fire Points** are the temperatures at which an oil begins to volatilize. Such tests are of practical value only in special applications where oils of very light viscosity must be used.

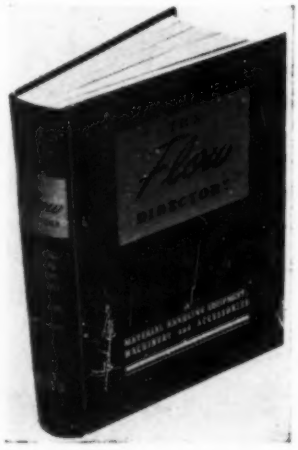
All tests referred to are covered by ASTM standards.

BOOK REVIEWS

Material Handling Directory

FLOW Directory of Material Handling Equipment, *produced by the publishers of the magazine FLOW (The Bolivar Publishing Co., 1240 Ontario St., Cleveland 13, Ohio) First Edition, 402 pages, 8x11 inches, profusely illustrated. Price $6.00.*

The FLOW Directory of Material Handling Equipment, the first of its kind, has been designed as a



reference guide for engineers and others responsible for efficient, low-cost material handling. The Directory is divided into five sections, the first of which is an equipment reference guide designed to establish a standard terminology in this important, growing field and to provide the user with an illustrated general description of each type of item. The second, third and fourth sections are alphabetic listings of manufacturers' catalogs, product classification index and trade names, respectively. The fifth section contains engineering data pertinent to the material handling field chosen for its usefulness in solving material handling problems in industry and commerce.

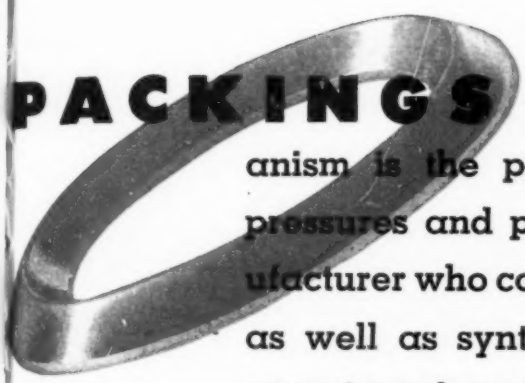
Servomechanism Fundamentals

Henri Lauer, Robert Lesnick and Leslie E. Matson, *Engineering Department, RCA Victor Division, Radio Corporation of America. First Edition. 274 pages, 6x9 inches. Published by McGraw-Hill Book Co., Inc., at $3.50.*

An introduction to the principles underlying the theory of servomechanisms, written primarily for the engineering student and the practicing engineer. Further, the book is an attempt to discuss the operating features of servomechanisms and to set forth systematic procedures for the design of such devices.

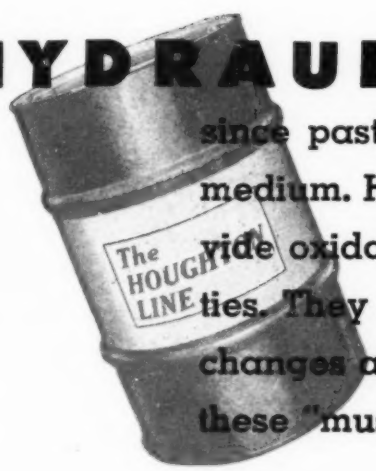
(Continued on page 46)

Why not "Ask Houghton" about



PACKINGS ?

A vital part of any hydraulic mechanism is the packing of proper type and design to hold pressures and prevent leakage. It pays to deal with a manufacturer who can provide a complete line of leather packings, as well as synthetic rubber; and who, further, can render expert engineering service on packing installations.

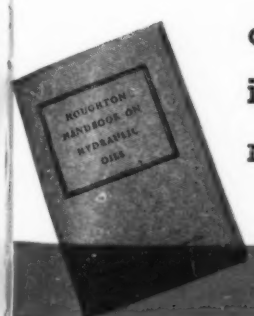


HYDRAULIC OILS ?

The day has long since past when just any oil can be used as the hydraulic medium. Hydraulic oils should be fortified by science to provide oxidation stability, gum solvency, anti-corrosive properties. They must have a high Viscosity Index to resist fluidity changes at varying temperatures. Engineers today recognize these "musts," and specify oils having these qualities.

Houghton supplies, and services, both...

We are the *only* source for both packings and hydraulic oils. We've had half a century of experience in both. We render an unparalleled engineering service on both. We pioneered in additive treatment to fortify oils for this purpose. For those reasons, it will pay you to consult Houghton on hydraulics.



HOUGHTON'S

HYDRO-DRIVE OILS *and*
VIM & VIX-SYN PACKINGS

For a free copy of the new Handbook on Hydraulic Oils, write E. F. Houghton & Co., 303 W. Lehigh Ave., Phila. 33, Pa.

USEFUL LITERATURE

(Continued from page 43)

21. Valve Bulletin... Bulletin VR-2 on ¾ in relief, sequence and unloading valves is being offered by The Denison Engineering Company. With ranges of adjustment to 5000 psi the valves are available in threaded body and subplate types.

22. Oil Handbook... This 48-page booklet "Handbook on Hydraulic Oils" is available from E. F. Houghton & Co. There are chapters on the selection of hydraulic oils by service properties, specifications, on the additive treatment of hydraulic oils and on trouble shooting. There is also a short chapter summarizing the qualifications of a good hydraulic oil. Additional chapters discuss the oils furnished by the company.

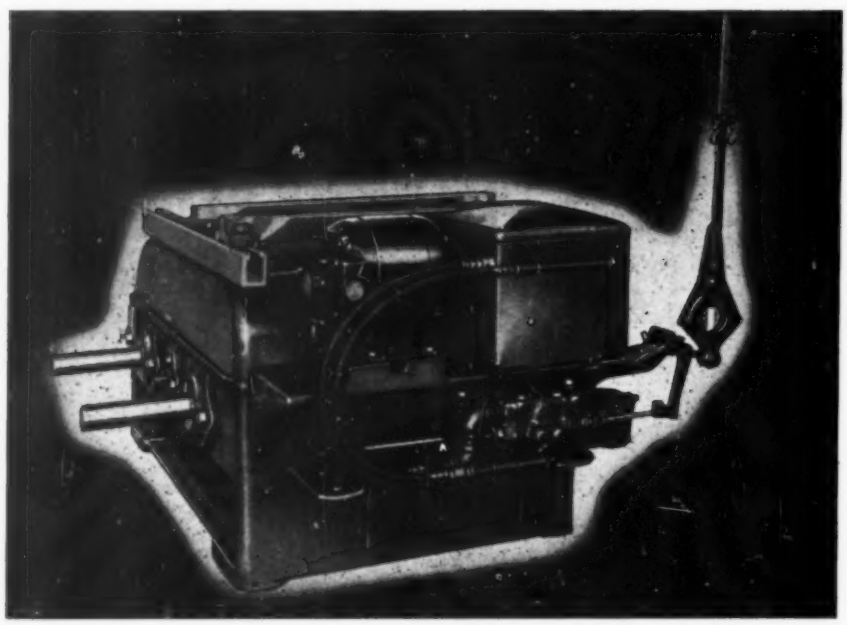
23. Graphitar Catalog... The 44-page catalog of The United States Graphite Company lists seals, rings, bearings, blades and other carbon-graphite components for hydraulic pumps, torque converters and transmissions. Physical properties of 32 grades are given.

24. Cylinder Selector... A slide rule hydraulic cylinder selector for convenience in computing both out stroke and in stroke pressure is offered to interested engineers and designers by Electrol Incorporated.

25. Filters... A 12-page illustrated bulletin issued by Cuno Engineering Corporation covers the two types of filter units made by this company. Selective flow tables and specifications of filter elements are included.

Hydraulic Automatic Control for Mechanical Transmission

An enclosed mechanical variable speed mechanism, actuated by a hydraulic system that provides speed changing from a very limited source of power; used for tension controls, velocity controls, synchronizing and rate of feed control.



This type of control is used in a wide variety of industries on processing equipment where sensitivity and accuracy of machine speed control are essential. It is widely used in such industries as textiles, paper, wire, machine tools and chemicals.

The indicating lever may be attached to any element or part of the driven machine from which indication of required speed may be taken. A double-acting cylinder and piston are mounted on the shifting levers of the mechanical transmission; the cylinder is connected to one pair of shifting levers, the piston rod to the other pair. The levers are positioned by a two-way control valve, operated by the indicating lever.

When a speed change is called for, the valve ports open, the cylinder movement spreads or closes the shifting levers. When the speed of the machine is correct, all ports of the operating valve close and a by-pass valve returns the oil to the reservoir. The control valve is actuated by as little as one ounce of pull, being double acting and having the valve a part of the system. There is no back lash nor lost motion.

BOOK REVIEWS

(Continued from page 44)

Examples, exercises and typical problems are given together with working formulas, curves and diagrams necessary for their solution.

Emphasis is placed on the transient analysis of elementary servomechanisms, five of the ten chapters being utilized for the development of the principles of this method. The book is a result of the authors' design and wartime teaching experience, and it does a good job in providing the engineer with a systematic design procedure for fulfilling specified operating requirements.

Elementary Fluid Mechanics

John K. Vennard, *Associate Professor of Fluid Mechanics, Stanford University. Second Edition. 339 pages, 5½x8¼ inches. Published by John Wiley & Sons, Inc., at $4.00.*

The second edition of this basic study on fluid mechanics is unusual in that it is shorter than the first while at the same time covering more material.

The principal change in the text is that the original chapter on ideal fluid flow has been expanded into three: incompressible fluid, compressible fluid and the impulse-momentum principle. The chapter on fluid flow in pipes has been rewritten and more practical pipe-line problems added. Mathematical developments have been condensed and some topics which experience indicated were beyond the capacity of the beginner were omitted.

Compressed Air Handbook

"Compressed Air Handbook", *published by Compressed Air and Gas Institute, New York, N. Y., First Edition, 400 pages 6x9 inches, 247 illustrations. Price $3.00 postpaid, anywhere in the United States; elsewhere $3.50.*

This is an authoritative guide for the proper installation, use and maintenance of air compressors and air-actuated equipment.

In addition to making available a mass of new material not heretofore published in a single volume, the Handbook contains, in revised and improved form, all the standard reference data formerly published as "Trade Standards". Included are definitions, test standards and numerous basic tables and formulas.

POST SCRIPTS OF INDUSTRY

NEWS · VIEWS · TRENDS

A committee working on the standardization of hydraulic elements for machine tools and representing the automotive industry and the National Association of Machine Tool Builders, held another meeting early this month in Detroit. A number of representatives of high pressure pump manufacturers were also present. The work is reported well under way but no reports or recommendations are expected for some months.

Two additions have been made to the sales of organizations of Sundstrand Hydraulic Division of The Sundstrand Machine Tool Co., Rockford, Ill. P. A. Anderson has been named eastern sales representative, while western representation has been taken over by the Burgan Machinery Co., Inglewood, Calif.

C. S. Davis, president Borg-Warner Corporation recently disclosed that construction projects to increase the manufacturing facilities of six divisions were under way or will soon begin. Among these is a $120,000 laboratory to be erected in Bedford, Ohio, a suburb of Cleveland, as a part of an expansion program for the Pesco Products Division.

L. S. Barksdale, President, Saval Company announces the appointment of C. E. McCuan as field representative for that organization. Mr. McCuan will be in charge of all agencies east of the Rocky Mountains.

A. S. Terry, Grand Haven, Mich., has been named sales manager of air motors and controlled air devices by The Bellows Co., Akron, Ohio.

The James P. Marsh Corporation, formerly of Chicago, is now occupying their new plant in Skokie, Ill. The facilities of the new plant, about twice the space of their former plant, are already reported taxed to capacity.

The SAE Committee A-6, Aircraft Hydraulic and Pneumatic Equipment, held a 3-day meeting at the Van Cleve Hotel, Dayton, Ohio, October 30-November 1, which was also attended by hydraulic engineers representing industry, the major air lines and government agencies.

Chairman B. R. Teree, engineering manager, The Weatherhead Company, reported attendance of nearly one hundred men and that a total of 45 projects were reported on and discussed. A number of new projects were assigned to sub-committees.

The next meeting of the Committee is scheduled for early in May.

The Hydraulic Hi-Speed Division of Double A Products Co., Inc., are now located in their new plant at Manchester, Mich. John J. Pippenger, engineering and research supervisor, states that delivery time of products has been reduced due to their new increased facilities.

(Continued on next page)

In applied hydraulics

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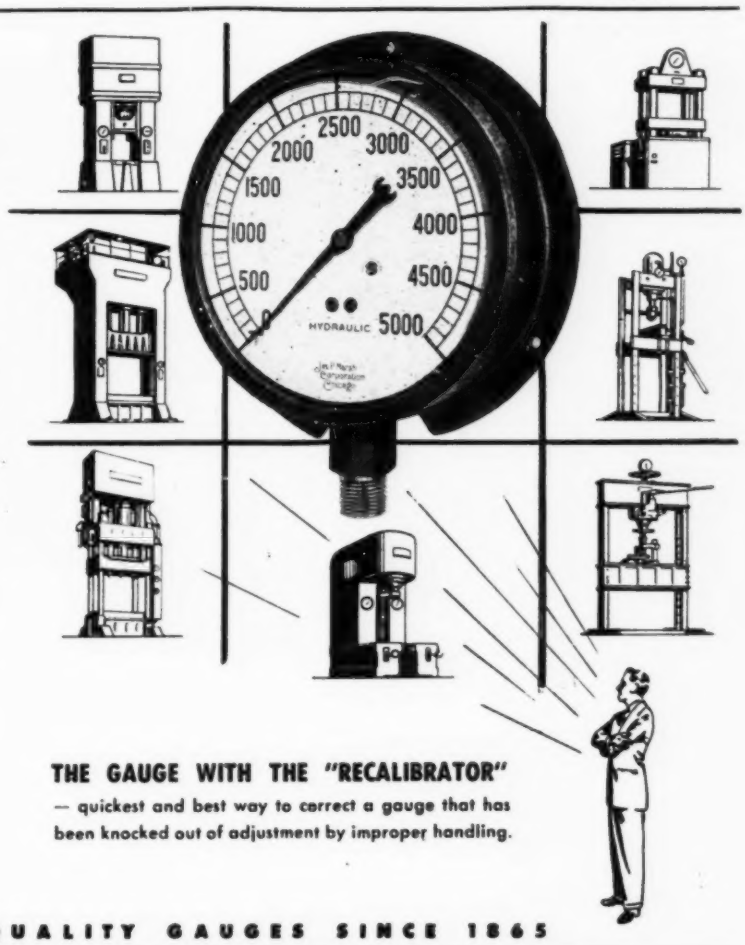

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Sales offices are still maintained at Detroit, with Ray J. Murphy providing engineering services for those interested in hydraulic oil control systems.

D. O. Thomas, president, Bendix-Westinghouse Automotive Air Brake Co. announces the appointment of Stephen Johnson, Jr. as chief engineer. Mr. Johnson will serve directly under Ellery R. Fitch, director of engineering.

David G. Henderson has been appointed Sales Engineer in the Pittsburgh area by The Hannifin Corp.

Raymond D. Johnson of Fort Lauderdale, Fla., formerly a construction engineer in New York, was awarded the Holley Metal at the annual meeting of the ASME in December for his work as a "pioneer in hydraulic engineering."

Peter F. Hurst has been elected President of Aeroquip Corporation, Jackson, Michigan. Mr. Hurst was instrumental in the organization of Aeroquip Corporation in 1940, and was previously its Executive Vice President and General Manager. He is also a Director and President of Eltron, Inc., of Anotreat, Inc., and Metalco, Inc., all of Jackson, Mich.

Hurst is a member of the S. A. E. and the Institute of Aeronautical Sciences.

Albert Musschoot has been appointed assistant to the chief engineer at Link-Belt Co. Formerly a member of the general engineering staff at Philadelphia, he will make his headquarters in Chicago. During the war, Mr. Musschoot worked on both mechanical and hydraulic equipment for the Army Ordnance Department. His background includes development work on power transmission and conveying machinery.

On January 1 Vice Admiral George F. Hussey, Jr., USN (ret.), wartime chief of the Navy Bureau of Ordnance, became administrative head of the American Standards Association, New York City.

The American Society of Lubricating Engineers will hold their third annual convention at the Statler Hotel in Buffalo, N. Y. April 19, 20 and 21. For the first time industrial exhibits will be a part of the meeting. Industrial lubricants and lubricating devices will be shown along with new and improved methods of application.

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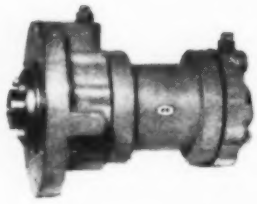

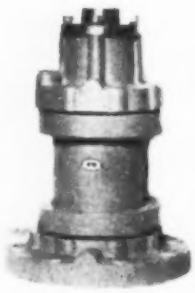

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